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THE JOURNAL

OF THE

Canadian Mining Institute

1909

EDITED BY THE SECRETARY

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VOLUME XII

"The Institute as a body shall not be responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at its meetings."—*By-Laws, Par. xxxix.*

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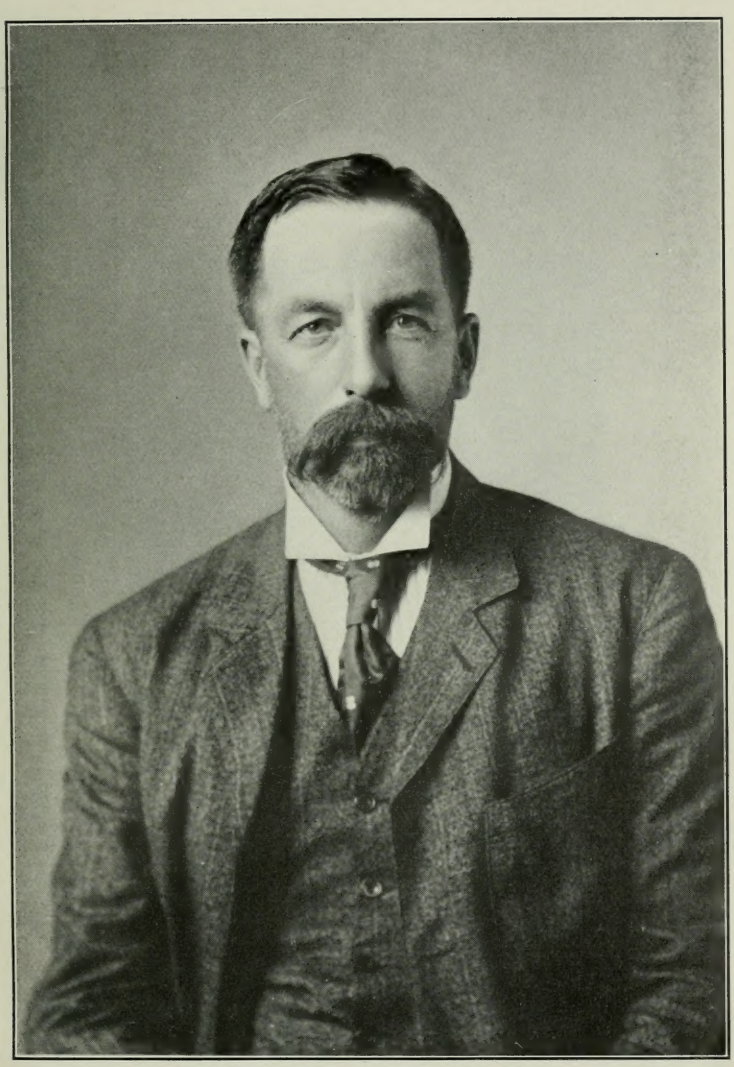

DR. WILLET G. MILLER,

Provincial Geologist of Ontario, elected President Canadian Mining Institute, March, 1908, re-elected President, March, 1909.

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THE LATE E. L. FRALECK.

Member of Council Canadian Mining Institute, whose death occurred at Cobalt, Ont., on May 27th, 1909.

CANADIAN MINING INSTITUTE

List of Officers and Members of Council since the Establishment of the Institute showing the years during which office has been held.

PRESIDENT

Coste, Eugene, 1903, 1904,
Fergie, Charles, 1901, 1902.
Fowler, S. S., 1900.
Hardman, J. E., 1898-99.
Keffer, Frederic, 1907.
Miller, Dr. W. G., 1908, 1909.
Smith, G. R., 1905, 1906.

VICE-PRESIDENT

Adams, Dr. F. D., 1901, 1902, 1903. 1905, 1906.
Barlow, Dr. A. E., 1908, 1909.
Blue, John, 1898-99.
Cantley, Thomas, 1905.
Carlyle, W. A., 1898-99.
Chambers, R. E., 1903, 1904.
Coste, Eugene, 1902.
Dawson, Dr. G. M., C.M.G., 1898-99.
Donkin, Hiram, 1899, 1900.
Drummond, Geo. E., 1899, 1900, 1908, 1909.
Duggan, G. H., 1905, 1906, 1907.
Fergie, Chas., 1898, 1899, 1900.
Fraser, Graham, 1901, 1902.
Goodwin, W. L., 1905.
Hedley, R. R., 1901, 1902.
Hobson, J. B., 1903, 1904.
Keffer, F., 1905, 1906.
Kirby, E. B., 1904.
Leckie, R. G., 1905, 1906.
McArthur, James, 1900, 1901.
Miller, Dr. W. G., 1907.
Obalski, J., 1909.
Porter, Dr. J. Bonsall, 1907, 1908.
Robertson, W. F., 1907, 1908, 1909.
Smith, G. R., 1903, 1904.

COUNCILLORS

Adams, F. D., 1899, 1900, 1904, 1907, 1908.
Aldridge, W. H., 1905, 1906, 1907.
Barlow, Dr. A. E., 1905, 1906, 1907.
Bennett, B., 1902, 1903.
Blakemore, Wm., 1898-9.
Blue, Archibald, 1898-9.
Blue, John, 1905, 1906.
Brent, Charles, 1899, 1900.
Brewer, Wm. W., 1908, 1909.
Brigstocke, R. W., 1909.
Brock, R. W., 1907, 1908, 1909.
Brown, J. Stevenson, 1909.
Browne, David H., 1907, 1908.
Cantley, T., 1903, 1904, 1905, 1906, 1909.
Chambers, R. E., 1901, 1902.
Cirkel, F., 1903, 1904.
Cole, Arthur A., 1908, 1909.
Coll, C. J., 1905, 1906, 1909.
Coste, Eugene, 1899, 1900.
Cowans, J. R., 1899, 1900.
Craig, B. A. C., 1905, 1906, 1907.
DeKalb, Courteney, 1901, 1902.
Dimock, C., 1898-9.
Donkin, H., 1898-9.
Donnelly, J., 1909.
Drummond, Geo. E., 1898-9.
Drury, H. A., 1908, 1909.
Duggan, G. H., 1903, 1904.
Fergie, Chas., 1908, 1909.
Fowler, S. S., 1898, 1899.
Fraleck, E. L., 1909.
Fraser, Graham, 1904.
Galt, E. T., 1899, 1900.
Gilman, E. W., 1907, 1908.
Gilpin, Dr. E., 1903, 1904.
Goodwin, Dr. W. L., 1903, 1904.
Gwillim, J. C., 1905, 1906, 1907, 1908.
Hardman, John E., 1908, 1909.
Haultain, H. E. T., 1907, 1908, 1909.
Hay, Col. A. M., 1905, 1906, 1907.
Hedley, Robt. R., 1900, 1905.
Hersey, M. L., 1909
Hobson, J. B., 1898, 1899, 1901, 1902.
Hodges, A. B. W., 1909.

COUNCILLORS—*Continued.*

Hopper, R. T., 1899, 1900, 1905, 1906, 1907, 1908, 1909.
Keffer, Frederic, 1902, 1903.
Kerr, D. G., 1903, 1904.
Kirby, E. B., 1900, 1901, 1903.
Kiddie, Thos., 1905, 1906, 1907.
Kirkgaard, P., 1901, 1902.
Leckie, R. G., 1898–9, 1901, 1904.
Lewis, James F., 1900, 1901.
Libby, W. L., 1898–9, 1902.
Little, W. F., 1901, 1902.
Loring, Frank C., 1898–9.
Macdonald, Bernard, 1900, 1901.
McArthur, James, 1898–9.
McCall, J. T., 1901, 1902.
McConnell, R. G., 1900, 1901.
McEvoy, J., 1904, 1905, 1906, 1907, 1908.
McNab, A. J., 1908, 1909.
McNaughton, G. F., 1900, 1901.
Meissener, C. A., 1899, 1900, 1905.
Merritt, W. Hamilton, 1898–9.
Miller, Dr. W. G., 1904, 1905, 1906.
Obalski, J., 1898, 1905.
Parrish, S. F., 1903, 1904.
Parsons, W. F. C., 1908.
Penhale, J. J., 1898–9.
Poole, H. S., 1900, 1901.
Porter, J. Bonsall, 1902, 1903, 1905, 1906, 1909.
Robb, D. W., 1901, 1902, 1905, 1906, 1907, 1908.
Robbins, Frank, 1902.
Robertson, W. F., 1904.
Shields, Cornelius, 1902, 1903.
Sjostedt, E. A., 1902, 1903.
Smith, F. B., 1905, 1906, 1907, 1908.
Smith, Geo. R., 1898–9, 1901, 1902.
Smith, J. Burley, 1900, 1901.
Smith, O. B., 1908, 1909.
Snyder, F. T., 1898–9.
Stewart, R. H., 1908, 1909.
Tonkin, J. H., 1903.
Turner, A. P., 1902, 1903.
Tyrrell, J. B., 1908, 1909.
Williams, H. J., 1903, 1904, 1905, 1906.
Willmott, A. B., 1905.

SECRETARY

Bell, B. T. A., 1898, 1899, 1900, 1901, 1902, 1903.
Coste, Eugene (Acting Secretary), 1904.
Lamb, H. Mortimer, 1905, 1906, 1907, 1908, 1909.

TREASURER

Brown, J. Stevenson, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908.
Lecky, W. S., 1909.
Stevenson, A. W., 1898, 1899.

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MEETINGS

CANADIAN MINING INSTITUTE.

PROCEEDINGS OF THE ELEVENTH ANNUAL MEETING.

MONTREAL, March 3rd, 4th and 5th, 1909.

The Eleventh Annual General Meeting of the Institute was held in the Windsor Hotel, Montreal, on Wednesday, Thursday and Friday, March 3rd, 4th and 5th, 1909.

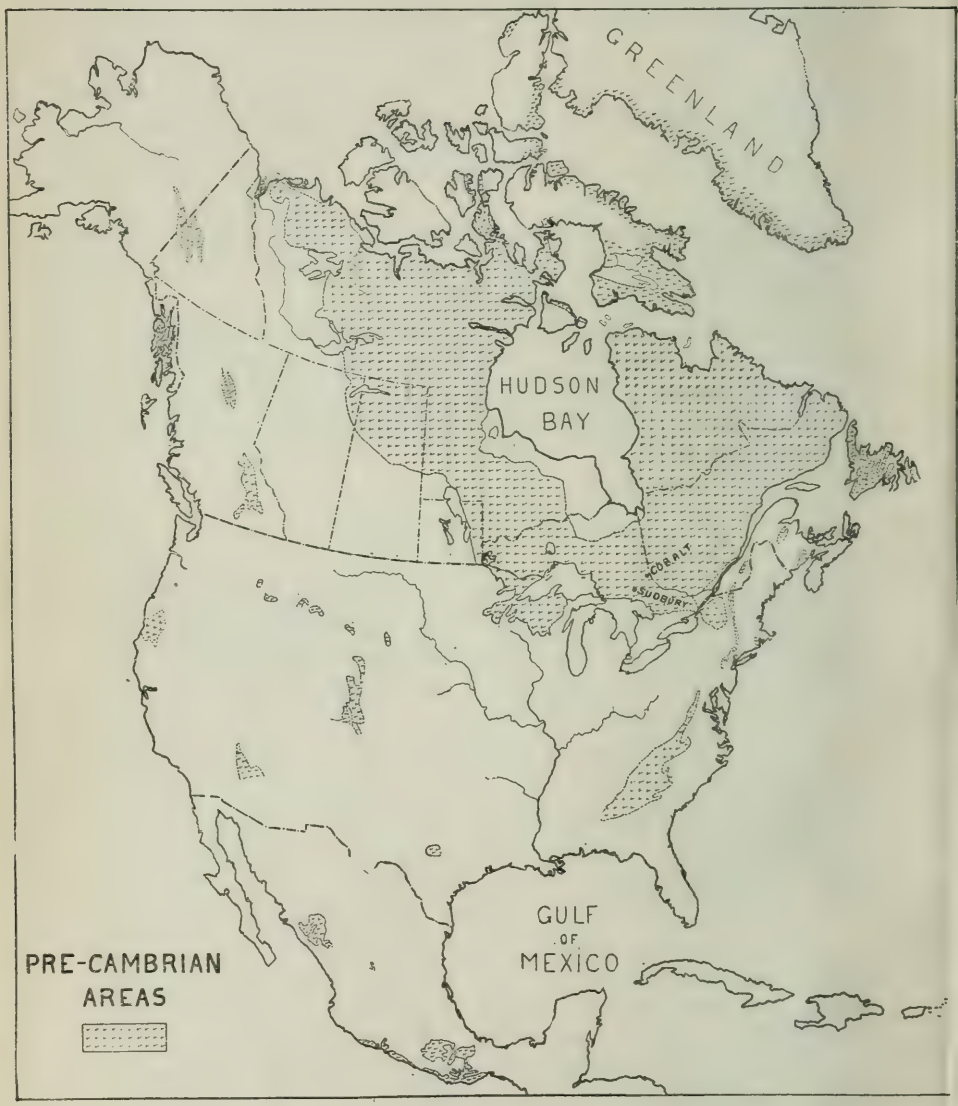
The members in attendance, to the number of over one hundred and fifty, assembled in the "Ladies' Ordinary" of the hotel on Wednesday morning at 10.30 o'clock, and the Proceedings were opened by the President, Dr. WILLET G. MILLER, who delivered the following address:—

PRESIDENTIAL ADDRESS.

"GENTLEMEN.—The Canadian Mining Institute, founded in 1898, has entered on its second decade. The questions may then be asked, what has the Institute accomplished, what progress has been made in the mineral industry during the last ten years and what is the outlook for the future?

"We have first to consider the work of the Institute itself. At the annual meeting in 1898 we had a membership of 63. At the present time our membership is about 850, including student members, and it is growing rapidly. We shall soon have a thousand. The Institute has covered a wide field. Its most important work, probably, has been that of the publication of papers. Our last annual volume consists of over 600 pages. Few of these papers would have been written had the Institute not existed. Mining men are proverbially reluctant to appear in print and their valuable experience is frequently lost. Local branches have much to do with getting papers. Men will prepare papers under local encouragement when they would pay little attention to written communications from the Secretary. Moreover the stu-

dent membership has had a beneficial influence in encouraging the budding members to write for our transactions.



Sketch Map showing the Pre-Cambrian Areas of North America. (See Presidential Address).

"When arrangements are completed for the establishment of libraries in connection with the branches, the work of the Institute will be broadened still further.

"During the ten years of its existence, the Institute has been called upon to give advice on legislation and on other matters concerning the mineral industry. Much more has been accomplished in this connection by the Institute than could have been achieved through other channels.

"Several excursions to mining centres have taken place and these have done much to make Canada's mineral resources known. Among these excursions may be mentioned that to British Columbia in 1899; that to Quebec province and to Nova Scotia, in company with the American Institute of Mining Engineers in 1900; that to Cobalt in 1907 and lastly that of 1908, from the Atlantic to the Pacific. This last excursion was a greater success than the most sanguine of our council or members could have expected it to be. The quality of the guests of the Institute from Great Britain and abroad insured success.

"The work of arranging for the excursion and carrying it to a success fell chiefly on our Secretary, Mr. Mortimer-Lamb, and on our Treasurer, Mr. Stevenson Brown. While their fellow members of council have expressed to these two gentlemen their pleasure at the success achieved by the excursion, this annual gathering seems to me a suitable place to thank our Secretary and our Treasurer on behalf of the membership at large for the care which they gave to the arrangements for the excursion. The Secretary is also to be congratulated on the bulletin which he has published, recording the events of the trip.

"At the last annual meeting both the Secretary and the Treasurer told me they intended to work with the object of making the past year the most successful in the history of the Institute. We have to thank them for the efforts which they have made and for the success which they have achieved.

"Mr. Stevenson Brown, having served as Treasurer of the Institute for the past ten years, is now retiring from that office. I can assure him that he has the best wishes of the members and we hope that his association with the Institute as its Treasurer will be a pleasant memory. When he recalls the early days of the Institute, the progress during later years and when he watches

the development in the future, it is to be hoped that Mr. Brown will find some recompense for the ten years in which he has served as an executive officer.

"Our Secretary, in the Excursion Bulletin, has referred to many men in various parts of Canada to whom thanks are due for the success of the trip. On behalf of the members generally I wish to again tender thanks to all. Time will not permit of my referring to individuals or organizations, but I wish to express thanks to another official of the Institute for the care with which the arrangements in the west were looked after. I refer to Mr. E. Jacobs, the Secretary of the Western Branch, who did much towards making the trip through British Columbia so successful.

"I have briefly described the work done by the Institute, but greater than all else are the opportunities which are given the mining men of Canada, from end to end of the country, of getting acquainted with one another. These annual meetings would be very valuable even if no papers were read. Men meet one another, compare notes and form friendships which they would have no other opportunity of doing. All this has a broadening effect and I am sure that every one of us after an annual meeting goes back to his work better equipped to carry it on.

"In the year 1898, when the Institute was organized, Canada's annual mineral output was valued at $38,412,431. In 1908 the value reached $87,323,000. This increase is highly satisfactory and offers encouragement for the future. It can be truthfully said, and without laying oneself open to the charge of boasting, that no country gives greater hope for the future in mining than our own.

"For years past there has been no doubt that the territory bordering on the Atlantic, with its great coal deposits and other mineral resources, has a bright future as a mining country. Similarly every one has agreed that the part of our country bordering on the Pacific ocean is destined to become great as a mineral producer. Mountains with the same characteristics extend from old Mexico and the United States through British Columbia and the Yukon. It has been estimated that the metal output of Mexico and the United States, in the mountainous tracts adjacent to the Pacific, has amounted to over $3,500,000 for each mile in length of these mountainous tracts. The Canadian territory to

the north has then great promise. While, therefore, all will admit that the Canadian territories on the Atlantic and those on the Pacific are destined to become centres of a great mineral industry, what is to be said of that vast Canadian region which lies west of the Acadian provinces and to the east of the Rocky Mountains?

"In the past, the people of Quebec and Ontario have heard little of their resources other than those of the forest and the soil. It has been difficult, as most of us know, to arouse much interest in the mineral possibilities of these two provinces.

"One half of the 3,750,000 square miles of Canada, chiefly in the provinces of Quebec and Ontario and in the territories to the north and north-west, is underlain by rocks of pre-Cambrian age. The mining experience of Canada has been drawn, naturally, largely from the United States, where the pre-Cambrian rocks cover a comparatively small extent of territory. It is but to be expected then, especially as the great part of the pre-Cambrian region of Canada is accessible with difficulty, that it would, up to the present, have attracted little attention as a mineral field. If we consider, however, what the pre-Cambrian region has already done, it seems to me we should feel that these vast areas of the old rocks give great promise. Personally, I feel no doubt about it. These pre-Cambrian regions are destined to be the centres of great mineral development.

"A small point of these old rocks extends from the north into the states of Minnesota, Michigan and Wisconsin. It is this pre-Cambrian area that has caused the United States to become the world's greatest producer of iron and steel; and the copper mines of Michigan have long been famous.

"The pre-Cambrian country over much of its surface offers little inducement to the agriculturist, although it possesses some fertile areas. Settlement has for this reason made little advance into the north, but along the thin line of settlement in Ontario we have, in the pre-Cambrian, Sudbury, the world's greatest producer of nickel, and the silver camp of Cobalt.

"Areas, underlain by rocks similar to those in the iron and copper fields of Michigan and in the iron ranges of Minnesota, and to those of Sudbury and Cobalt, are known to occur at numerous points over the 1,800,000 square miles of the Canadian pre-Cam-

brian regions. It does not require the vision of a prophet to foretell what will be the mineral development when our pre-Cambrian regions are adequately explored and prospected. The mining men of Canada, and their society the Canadian Mining Institute, have a great mineral field before them—half a continent. We are scarcely at the beginning. Let us make the best use of our opportunities. Let us avail ourselves of the experience of older mining countries, have faith in Canada and in ourselves and a firm belief in the future of our industry.

"In conclusion I wish to thank the members of council and the membership at large for the pleasant year I have had as the presiding officer of this Institute. My labours have been made light by the kind co-operation and assistance which I have received on every hand.

"I now have pleasure in declaring the 11th annual meeting of the Institute open for the reading of papers, the transaction of business and especially for social intercourse and the interchange of good fellowship."

The Secretary then read the Report of the Council for the year 1908–09, as follows:—

REPORT OF THE COUNCIL FOR THE YEAR 1908–09.

MEETINGS.

The Tenth Annual Meeting of the Institute was held at the Russell House Hotel, in the city of Ottawa, on March 4th, 5th and 6th, 1908, and was no less successful than those of recent preceding years; whilst the attendance of upwards of one hundred and fifty was the largest heretofore recorded. The Meeting was opened by the Hon. the Minister of Mines for the Dominion, Mr. William Templeman, who delivered an interesting address of welcome to the assembled members.

Other meetings have been held during the year at Rossland, Victoria and Greenwood in British Columbia under the auspices of the Western Branch; whilst the branches at Cobalt, Toronto, Kingston and Montreal have also held meetings at which papers have been presented and discussed.

Publications.

The papers presented at the Annual Meeting, together with some others read before the Branch Meetings or submitted direct to the Secretary, in all forty-two papers from members and student members, together with the discussions thereon, have been published in Volume XI, of the Journal of the Institute, which has been issued to members of the Institute in good standing.

There has also been published and distributed during the year four Bulletins, in which have been printed papers "subject to revision," notices and other matter of general interest to the membership. A larger edition, of two thousand copies, of a special Bulletin, containing a report of the Summer Excursion, together with brief descriptions of the several mines and works visited, was issued in January.

Summer Excursion.

The project referred to in the Report of the Council for last year, of inviting representatives of the several important mining and engineering societies of Great Britain and the Continent to take part in an excursion arranged and initiated by the Institute to the chief mining centres of the Dominion, was carried into successful effect during the year. The visitors, representing the Institution of Mining and Metallurgy; the Iron and Steel Institute; the Institution of Mining Engineers; the Mining Institute of Scotland; the South Wales Institute of Mining Engineers; and two continental societies, assembled to the number of twenty-three in the city of Quebec, on August 24th last, and were joined at other points later by fifteen others. Of these gentlemen twelve were official guests of the Institute. The tour was divided into three stages, of which the first included visits to the works of the Dominion Iron & Steel Company, the collieries of the Dominion Coal Company, and the works of the Nova Scotia Steel & Coal Company in Cape Breton, and to the principal asbestos mines in the Eastern Townships of the Province of Quebec. Stage II represented visits to the mines of the Cobalt district, to Moose Mountain, to the smelter plant and one of the important producing mines of the Canadian Copper Company, and the Mond smelting works in

the Sudbury district. Stage III covered a comprehensive tour of the mining areas of Alberta and British Columbia, and included visits to the International Coal Company's colliery at Coleman; the new plant of the Hosmer Mines, Ltd., at Hosmer; the Coal Creek colliery of the Crow's Nest Pass Coal Company; the St. Eugene mine at Moyie; the Consolidated Mining & Smelting Company's smelter at Trail; the Le Roi, the Le Roi No. 2, and the Centre Star mines at Rossland; the B. C. Copper Company's mine and smelter at Greenwood; the Granby Company's mines and smelter at Phœnix and Grand Forks; the West Kootenay Power Company's power plant at Bonnington Falls; the Blue Bell mine at Ainsworth; the Tyee Copper Company's smelter at Ladysmith; the Western Fuel Company's collieries at Nanaimo; the Pacific Coal Company's colliery at Bankhead, and the gas wells at Medicine Hat and Dunmore. The tour, which terminated on October 2nd, was in every sense an unqualified success, and the Council desires to record its sense and appreciation of the valuable services rendered by those members and others to whose generous assistance and co-operation may be attributed this eminently satisfactory result. In particular, thanks are due to the Dominion and Provincial Governments for support and encouragement; to the transportation companies, notably the Intercolonial Railway, the C. P. R., the Grand Trunk, the T. & N. O. Railway, and the Canadian Northern Railway Companies for the incomparable services and special accommodation and facilities they afforded; to the Mining Society of Nova Scotia whose officers undertook the arrangements in connection with the visit to Cape Breton; to the members of the Central Organizing Committee in Montreal; to Mr. Geo. R. Smith, the Chairman of the Quebec Committee; to Mr. R. W. Brock; Mr. James White and Mr. James McLeish, representing the Dominion Government on the excursion; to Mr. O. N. Scott and other members of the Toronto Committee; to Mr. A. P. Turner and Mr. D. H. Browne, at Sudbury; to Mr. Arthur A. Cole, the Chairman, and the other members of the Cobalt Committee; to Mr. O. E. S. Whiteside, in Alberta, and to Mr. A. B. W. Hodges, the Chairman, and the several members of committees in British Columbia.

MEMBERSHIP.

The increase in the membership of the Institute during the year is gratifying, there having been elected since the last Annual Meeting eighty-seven members, fifty-two associate members, and two student members. The memberships of the affiliated mining societies of McGill University and of Queen's also show substantial increases. Thus, at the close of the present year the membership, inclusive of student members, is, in round numbers, eight hundred and fifty.

The following gentlemen have resigned their membership:—Messrs. N. A. Belcourt, Chas. Biesel, Russell L. Blackburn, G. O. Buchanan, Fritz Cremer, A. L. Dean, Geo. W. Dunn, J. F. Forbes, Daniel Ford, W. M. Heron, Nelson P. Hulst, E. P. Kadeleck, John P. Kinghorn, F. H. Marsh, G. O. McMurtry, Geo. Monteith, J. B. Morrow, M. R. Morrow, Geo. W. Stuart, J. W. Tyrrell and H. M. Whitney.

The Council records with profound regret the death of Mr. Bennett H. Brough, Secretary of the Iron and Steel Institute, Corresponding Member; and of Mr. H. C. Hammond, of Toronto, Member.

In order to minimize the possibility of the admission to membership of undesirable or not properly qualified persons, the Council has recently resolved to issue a list at periodical intervals, containing the names of all applicants seeking election as members or associate members of the Institute. This list will in future be sent to members with a request that the names submitted be carefully scrutinized, and that any information concerning the proper classification or adversing the candidate's right to admission to the Institute be communicated to the Secretary prior to the submission of the candidate's name to the Council for election.

LIBRARY AND READING ROOM.

In view of the fact that the accommodation of the premises leased from the Canadian Society of Civil Engineers at 413 Dorchester St. West, Montreal, and occupied by the Institute since May, 1905, was found to be inadequate, in consequence of the recent rapid increase of the business of the Institute, it was deci-

ded at a meeting of Council, held in July last, to seek more commodious quarters, and in November an arrangement was entered into with the manager of the Windsor Hotel, Montreal, whereby the Institute has secured the use of two large rooms on the ground floor, namely, Rooms 3 and 4, for office and library purposes. In deciding to establish the office in the Windsor Hotel, the Council was influenced by the consideration that a majority of the members of the Institute visiting Montreal usually make this Hotel their headquarters, and it was believed that the housing of the library in the building would be greatly to their convenience. That there was ample justification for this assumption has already been demonstrated by the considerable increase of visitors, both members and others, who have made use of the library since its removal to the Windsor Hotel.

During the year a number of books have been added to the library. These include Government publications, periodicals, and transactions of sister societies received in exchange.

The Library Committee desires to express its thanks to the Cobalt branch of the Institute which, through its chairman, Mr. Arthur A. Cole, has presented to the library a complete collection of typical rock and ore specimens representative of the Cobalt district.

BRANCH LIBRARIES.

A beginning was made during the year in the direction of establishing branch libraries of the Institute in the several important mining centres of the Dominion; and the Secretary, having sought the co-operation of the heads of the Federal and Provincial Mines Departments, arranged to secure several sets of official reports and publications, which have since been forwarded to the secretaries of branches for the use of members in these respective localities. It is hoped that during the ensuing years means will be provided for the greater elaboration of the scheme as originally outlined.

SECRETARY'S OFFICE.

The following returns are taken from the records of the Secretary's office for the twelve months ending February 28th, 1909:

Correspondence—Letters mailed, 2,559; Circulars, etc., issued, 12,200; Papers, Bulletins and Transactions issued, 6,200.

FEDERAL DEPARTMENT OF MINES.

The part taken by the Institute in influencing the establishment of a Federal Department of Mines, warrants the Council in expressing gratification that progress has been made in the organization of this Department. It desires, meanwhile, to congratulate the Government on the appointment of Mr. R. W. Brock to the directorship of the Geological Survey, and welcomes the return to Parliament of the Hon. Mr. Templeman, Minister of Mines.

STUDENT COMPETITION AND AWARDS.

In 1908 ten papers were submitted by student members in competition for the awards annually offered by the Institute. After receiving the report of the judges, Mr. Chas. B. Going, Editor of the *Engineering Magazine*, and Mr. H. H. Stoek, Editor of *Mines and Minerals*, the Council awarded the President's gold medal to Mr. Harry H. Yuill, of McGill University. In addition, Mr. Yuill received a cash prize of twenty-five dollars. Cash prizes of twenty-five dollars each were also awarded to Messrs. A. A. Pare and Mr. L. Stewart, both undergraduates of McGill University. In recognition of the interesting and valuable paper contributed by Mr. B. Neilly, of Toronto University, on the subject of "Refining of Silver Bullion Containing Arsenic and Antimony," a special prize was voted by the Council to be awarded to that gentleman. The following extract from the report of the judges may be of interest to members:—

"As judges under your appointment to examine the papers submitted in the student competition of the Institute, and to indicate those which seem to us most deserving of merit, we have carefully considered the ten papers which have been offered this year and have reached the unanimous decision which is expressed below.

"In the process of consideration we have taken account of the general treatment, the originality of the work, the costs and technical data embodied, the style and English, illustrations, and references and bibliography, using a system of comparative markings to check the general impressions received from the papers as a whole.

"Mr. H. H. Yuill's paper on 'The White Bear Mine, Rossland, B.C.,' impresses us as being excellent in composition, well arranged, and well proportioned, accompanied by valuable cost data and excellent illustrations representative of the author's own work. Beyond this, it is characterized by a quality of constructive criticism which, in summing up the qualities of the leading papers, raises this to the first place.

"Mr. A. A. Pare's paper on 'Mining and Mining Methods of the Yukon' is noteworthy for the peculiar interest of its subject matter and the fullness of its technical data, figures of costs, and diligence in making use of opportunities for obtaining material which in general would be difficult to get. There is not, however, so clear an evidence of patience in digesting the information as appears in Mr. Yuill's paper, and we feel that for that reason Mr. Pare's paper should be placed second.

"Mr. L. Stewart's description of 'The Creighton Mine of the Canadian Copper Co., Sudbury District, Ontario,' is a comprehensive, concise, well-ordered description, generally adequate to that purpose. It shows a good sense of organization and faculty for clear expression. The illustration is not so good as in the preceding articles, the subject matter not ratable as high in originality as in Mr. Pare's paper, and the mode of treatment more purely descriptive than in Mr. Yuill's—that is, not exhibiting so plainly a faculty for judgment and criticism. For these reasons, while we commend the paper highly for its excellence, we feel that it falls into third place.

"All these articles are excellent in typographical preparation and in general regard for neatness of appearance and for convenience of the reader. Indeed, with few exceptions, the whole group submitted this year are above the average in these respects.

"Mr. B. Neilly's paper on 'Refining of Silver Bullion Containing Arsenic and Antimony,' has impressed us very favourably as a clearly-presented report of original work, which appears in itself to possess technical value.

"The papers of Mr. A. O. Hayes on 'The Occurrence and Treatment of Nickel-Plate Gold Ore at Camp Hedley, B.C.'; of Mr. J. P. Corduke's on 'The Manufacture of Coke in Alberta'; of Mr. K. S. Twitchell on 'A Description of a Modern Blast-Furnace Plant'; of Mr. Stuart A. Schofield on 'The Origin of Some of the

Deposits of the Eastern Ontario Gold Belt'; and Mr. W. M. Harding on 'Coal Mining in Southern British Columbia,' have certain points of merit.

"It is, therefore, our recommendation, subject to the judgment of the Council, that the awards be made to Messrs. Yuill, Pare and Stewart, in the order given, and that honourable mention be given to Mr. B. Neilly."

H. MORTIMER-LAMB,
Secretary.

The Secretary added:—"There is one matter not specifically referred to in this Report and to which I might call attention, and that is that our student membership has been considerably increased by the large enrollments during the year from the School of Mining, Kingston, whose local mining society, which is affiliated with the Institute, has now a membership of eighty-seven as against forty-seven in 1908.

"I might also remark as an interesting fact—perhaps unique in the annals of societies such as ours—that a lady last year applied for and was admitted to membership in the Institute. I allude to Mrs. Rosylin Young, of Victoria, B.C., the wife of the Provincial Secretary, and who is also, I believe, a science graduate of McGill University, and a very capable geologist." (Applause).

On motion of Mr. COSTE, seconded by Mr. TYRRELL, the Report of the Council was adopted.

FINANCIAL STATEMENT AND AUDITORS' REPORT.

The Treasurer presented a statement showing receipts and disbursements for the year ending February 1st, 1909, as follows:—

RECEIPTS.

Balance February 1st, 1908			$3,472.69
Subscriptions—			
483 ordinary members at. .	$10.00	4,830.00	
48 Half year "	5.00	240.00	
7 Student "	2.00	14.00	
University "	1.00	42.00	
Arrears collected		320.00	
			$5,400.64

One Life Membership	100.00
Interest	76.35
Publications	57.00
Advertising	109.75
Badges	20.00
Banquet Tickets	252.00
F. Keffer (Medal)	20.00
Dom. Govt. Grant	3,000.00
Publication & Printing per Summer Excursion	2,500.00
	$15,053.79
Less Disbursement per Statement	$11,924.80
Balance on hand	3,128.99

Audited and certified correct.

(Signed) P. S. Ross & Sons,
Chartered Accountants.

J. STEVENSON BROWN,
Treasurer.

MONTREAL, QUE., Feb. 22nd, 1909.

SUMMARY STATEMENT.

SHOWING DISTRIBUTION OF DISBURSEMENTS TO THE VARIOUS WORK AND BUSINESS OF THE INSTITUTE.

Publication—		
Transactions, Vol. X.	$ 700.00	
" Vol. XI.	5,528.96	
Postage and Express	365.80	
Sundries	24.54	
		$6,619.30
Library—		
Rent	552.59	
Binding & Books	251.06	
Furniture	310.90	
Telephone	40.00	
Sundries	55.11	
		1,209.66

Meetings—			
Annual		883.15	
Council		57.60	
			940.75
Secretary's Office—			
Salary	$2,100.00		
Less chargeable to Pubn.	1,600.00	500.00	
Printing, Stationery, &c.		239.67	
Postage, Telegrams, &c.		177.23	
Travelling Expenses		177.80	
Sundries		279.18	
			1,373.88
Treasurer's Office—			
Treasurer's Grant		500.00	
Printing, Stationery, &c.		110.45	
Postage		91.50	
Bank charges on cheques & drafts		118.10	
Sundries		78.35	
			898.40
Branches—			
Western Branch		567.40	
Toronto Branch		38.94	
Kingston Branch		3.00	
Montreal Branch		26.27	
			635.61
Sundries—			
Advertising		50.00	
Prizes		75.00	
Various		122.20	
			247.20
			$11,924.80

Audited and certified correct.

(Signed) P. S. Ross & Sons,
Chartered Accountants.

MONTREAL, QUE., Feb. 22nd, 1909.

"It may not be out of place to say, that the financial statement just submitted, covers what may be called the most active year in the history of the Institute; while the receipts and disbursements have been larger than those of any preceding year. There are no outstanding liabilities, and my successor in office, will have a comfortable balance with which to start the new year's business.

"It is encouraging to note the substantial increase in revenue, derived from membership fees, amounting to $988.00—being an increase of almost 25%. This increase would have been considerably augmented, were it not for the fact that under a new rule, members elected after July 1st, only paid a half year's subscription. The figures compared with last year, not including arrears collected, are as follows:—

For year ending 1st February, 1908..	$4,138.00
For year ending 1st February, 1909..	5,126.00
Increase.....	$988.00

J. STEVENSON BROWN,
Treasurer.

The Treasurer added:—I wish to compliment our members on their loyalty to the Institute during the ten years I have had the honour to be Treasurer. Thus the amounts outstanding on account of annual subscriptions are relatively small, and I think I can say that we have not lost from arrears of this nature, during the period to which I have referred, a sum aggregating five hundred dollars. This is a most creditable showing and it has been one of the most satisfactory features of my office that the loss in this regard has been so trifling. (Applause). In reference to the balance carried forward from last year, viz. $3472.69, it should be remembered that there was an outstanding liability of $700.00 and therefore the net balance at the credit of the Institute (all accounts paid) was $2772.69 as against a balance this year (with no liabilities) of $3,128.99—an increase of $456.30.

Auditors' Report.

The President read the report of the auditors, as follows:—

Montreal, Feb. 24th, 1909.

To the President and Council
Canadian Mining Institute, Montreal.

Gentlemen:—We beg to report that we have audited the Receipts and Disbursements on account of your Institute, as recorded in the books of your Treasurer, for the year ended on the 31st January, 1909.

The amounts received during the year have been properly accounted for, while the disbursements have been covered by duly approved vouchers.

The expenditure has been divided under various heads in the financial statements to be presented at your Annual Meeting and which we have certified as correctly setting forth the transactions of the Institute for the year, according to the books.

We have checked the Bank Accounts for the year and the balances shown by them have been satisfactorily accounted for. All of which we have pleasure in reporting.

Respectfully submitted,
P. S. Ross & Sons,
Chartered Accountants.

Mr. Drury:—In my opinion, it would be very desirable if, in future, the treasurer submitted a comparative statement of receipts and disbursements. Our membership is increasing very rapidly, but the expenses are increasing in vastly greater proportion, and I beg to suggest that in future expenditures should be regulated by committees instead of by individuals.

Mr. Tyrrell:—I suggested at the last Annual Meeting that the Treasurer's Report should be printed and distributed to members in advance, and I desire to repeat my proposal in this respect.

DR. PORTER:—We might even go a step further and print both the Treasurer's Statement and the Annual Report of the Council in advance of the Meeting. If then these contained any matters to occasion controversy, members would have an opportunity to consider the points of issue at their leisure and afterwards discuss them at the meeting more intelligently. If I am in order I should like to recommend that hereafter the Annual Report of Council, including the Treasurer's Report, be printed and distributed in advance of the Annual Meeting.

DR. BARLOW:—In my judgment this is a matter that should rest with the Council. If the books were closed at the end of December, instead of at the end of February, it would be easy enough to print a financial statement in advance of the Annual Meeting, and unquestionably this course should be adopted. Referring to the question of increased expenditures, this is a situation we must be prepared to face if we desire the Institute to extend its scope and usefulness. For example, means must be provided to enable the Secretary to periodically visit the several branches, and so long as we have money in the treasury we should not be afraid to spend it in advancing the interests of the Institute.

DR. PORTER then moved, seconded by MR. TYRRELL, that in future the Annual Report of Council, including the Treasurer's Report, be printed and distributed to members in advance of the Annual Meeting.

The motion was carried.

The Treasurer then read a letter from Mr. J. Obalski, Superintendent of Mines for the Province of Quebec, announcing that the Provincial Government had decided to appropriate the sum of one thousand dollars as a grant to the Institute.

The President, remarking on this donation, said that it should be very gratifying to the members to receive this tangible evidence of the recognition of the Quebec Government of the usefulness of the work of the Institute. The Quebec Government had set an example which it was hoped the other Provinces would emulate. The Western Branch had discussed the prospect of securing a grant from the British Columbian Government, and he thought that this voluntary action on the part of the Quebec Government might well be used by Western members as an argument in urging their claims in this regard. The Government of Ontario had on

several occasions made grants of money to the Institute, but he hoped that, in time, all the Provinces in which mining was carried on would be equally responsive. Grants from Provincial Governments might be devoted to special purposes; for example, to the maintenance of branches, and this would especially apply in the case of the West.

THE INSTITUTE'S POLICY RESPECTING BRANCHES.

DR. BARLOW:—When is it proposed to take up the discussion of the question of the policy the Institute is to pursue in the near future? The scope of the Institute certainly can be extended far more widely than at the present time. When the branches were organized it was not with the idea of leaving them to themselves. Their natural tendency will be to isolate themselves unless we have some definite scheme to bring them together and make them feel that the Mining Institute is the *Canadian Mining Institute*, and that the branches are serious adjuncts of the parent society. (Applause).

MR. A. A. COLE (Chairman of the Cobalt Branch):—At Cobalt we have a very rapidly increasing membership and our Branch is becoming a very important organization. We do not, however, feel at all that we are anything but a part of the Canadian Mining Institute (Hear, hear); but we feel that we are an important part, and we feel that we should get a certain amount of support to carry on work that is not called for in other branches. This discussion on the future general policy of the Institute is, I conceive, opportune at the present time, because we have great ideas in our Cobalt Branch, and we would like to receive support to carry them into effect. I think that when those ideas are laid before the Institute it will be found that we are not only in the interest of the Cobalt Branch, but in the interest of the Institute (Applause); and I do not hesitate to say that you can depend on the Cobalt Branch to stand heartily by the Institute, and you need not be afraid that we will start any agitation that will tend towards separation from the parent organization (Applause); we do, however, want something in the way of definite support and encouragement, and now is the time we most need it. At the present time, we have no meeting room. The town council has,

however, promised us a room, and we are anxious to fit it up for the uses of the Branch.

I might say that the Cobalt Branch in the last two years has only received one grant, to the amount namely of $50.00, which was devoted towards the expense of the reception of the American Institute members when they visited Cobalt. The Secretary of the Canadian Mining Institute asked us what we were prepared to do in the way of entertaining these visitors, and from that enquiry we inferred that we should receive financial assistance from the Institute headquarters when we applied for it, but, as I have stated, we were only assisted to the extent of fifty dollars.

Last year a special grant was appropriated for entertaining the Institute when they came to Cobalt; but beyond these two grants we have not received a cent from the Institute. Now, while there is a clause in the by-laws of the Institute to the effect that branches are entitled to one-fourth of the fees of the members thereof in good standing, we have never made an application for this appropriation. We would like, however, to know what assistance we can depend on receiving from the central organization in the future.

THE TREASURER:—We give the members for their ten dollars' subscription a copy of the Transactions, this year's volume, comprising about 600 pages. In addition to that, we give each member a quarterly Bulletin of anywhere from a hundred and fifty to three hundred pages. Now, taking it all in all, I think any man who ever refers to the Transactions will admit that he is getting a great deal for his ten dollars. The total membership fees at the present time are in the neighbourhood of five thousand dollars. You have $2,100 to pay your Secretary and also a grant of $500 to the Treasurer. Now, what have you left, if, out of this $10 subscription, the Institute should be obliged to refund to branches (say) twenty-five per cent.? The Institute would be bankrupted at once. I do not wish to be understood as speaking against the principle of aiding the branches to the fullest extent of our financial ability, but we must not so deplete our treasury that at the commencement of the year, we could only show a small balance; because in my experience the bulk of our subscriptions to the Institute come in after the first of July, and the Government grants are seldom available before that date; so that unless the

Treasurer is able to start his year with a good round balance in hand, he certainly cannot carry on the work of the Institute properly.

Then it must not be forgotten that the Canadian Mining Institute in its work is endeavouring by all possible means to encourage the mining student, in the different colleges affiliated with the Institute, and from each of these students we collect simply a nominal fee of $1.00, so that they can feel they are contributing something, and not getting something for nothing. Now, all student members receive copies of the Transactions as they are issued, and in the present condition of the finances of the Institute, unless the membership is largely augmented or the membership fee increased, if we are obliged to pay out any considerable proportion of our income to these branches, it will be utterly impossible for the Institute to continue to do the educational work that it is striving to accomplish. (Applause).

MAJOR LECKIE:—This Institute was formed, as has been already remarked, in 1898, by the federation of the Provincial Societies. At that time there was a very vigorous society here in the Province of Quebec, and another society, which was very much alive at the time, was that of Nova Scotia. By mutual understanding a Federated Institute was organized. Mr. B. T. A. Bell was Secretary and I was elected the first President of this Federated Institute, which was then called the Federated Canadian Mining Institute. Now, it seems to me, we must give a good deal more attention to local organizations. They are the ones which will keep the interest in this Institute alive, and it is a very good suggestion that our Secretary should give a good deal of time to the local organizations and create local interest in the parent society.

DR. BARLOW:—With reference to what Mr. Cole and Mr. Brown have said, it seems to me it would have a beneficial result if we decided the point of the monetary assistance to be afforded branches. They require some assurance in the matter. In the near future we should see that a branch is formed in Ottawa; we should make further and renewed attempts in connection with Nova Scotia, or else we should found a separate branch of the Canadian Mining Institute in Nova Scotia. The general policy of the Institute with regard to these branches must be clearly

defined and clearly carried out. Up to the present time, Cobalt has been very magnanimous and has not asked for assistance, but now the Branch desires to know what financial help it can expect in the future. British Columbia is knocking at the door for increased recognition in this regard, so that the question is a live one, and I would like to see a committee formed, to consider what steps should be taken in this matter. It seems to me if greater efforts were made in the direction of missionary work, in strengthening the branches, and if the Secretary should visit them periodically, we would see a greater interest taken in the Institute in the near future.

MAJOR LECKIE:—I might call your attention to the fact that this week the Nova Scotia Mining Society holds its Annual Meeting in Halifax. Now I remember at the first meeting of our Association here, we had a representation of probably twenty men or more from Nova Scotia, and now there is not one. I would like to know if there has been any communication from the Nova Scotia Mining Society, or if any attempt has been made to maintain a correspondence with them.

THE SECRETARY:—Two attempts have been made to induce the Mining Society of Nova Scotia to enter into some affiliation arrangement with this Institute. I went down to Halifax some three years ago, and then suggested the plan that we should publish and incorporate their transactions with our own, on terms very favourable to the Nova Scotia Society. The proposal, however, was not entertained. Again, later, an attempt was made on somewhat similar lines, but failed; and last year our President and Mr. Brock attended the meeting of the Society and, I understand, were satisfied that little could be done in this direction by the Institute. Meanwhile, however, the majority of the men engaged in the direction of important mine operations in Nova Scotia are members of this Institute.

DR. LEDOUX:—My personal feeling in this case, now before us, would be that it might be very well to consider the policy of not contributing to the expense of each individual branch; but allowing sections to organize clubs and societies as they see fit, and obtain money for expenses for such organizations directly in the locality most interested. For instance, at Cobalt there

are many mining companies, very well to do that, doubtless, would be very glad to make appropriations for a local mining club, or a mining society. The expenses of keeping up an organization of that kind, it seems to me, would be trivial; but it would permit each individual member to retain his membership in the parent society, and the different papers read could be presented later on at a meeting of the general association and could be printed in the general transactions; and in that way you would not run the risk of separation or segregation of the societies, each, as a separate branch, having no connection with the mother society.

I think that something of that kind should be considered, and while I do not know what the general sentiments of the members present would be, I venture to suggest that this matter should be referred to the Council with instructions to consider it and recommend at some subsequent meeting of this body prior to our adjournment on Friday. (Applause).

MR. COLE:—I may remark that I am merely asking for information with regard to the policy to be pursued by the Institute, so that we may know what to expect in the future. We feel that we are very much a part of this Institute.

MR. COSTE:—I think that this question has been sufficiently discussed and I would move that the matter be left to the Council to deal with, feeling quite sure that it will be satisfactorily dealt with, and that our members in the different branches will continue to work in the interests of the Institute, with the same loyal spirit that they have always displayed towards it. (Applause).

DR. BARLOW:—I am quite agreeable to Mr. Coste's motion and heartily second it.

THE SECRETARY:—I have here a resolution forwarded to me by the Secretary of the Western Branch, which is relevant to this discussion.

The resolution was passed at a general meeting of the Western Branch, held at Greenwood, British Columbia, on Tuesday, January 26, 1909, and reads as follows:—

On motion of Mr. Frederic Keffer, seconded by Mr. S. E. Belt, after discussion, it was unanimously resolved:—

"That the Council of the Western Branch request at the next "general meeting of the Institute in Montreal that, in view of the "isolation of the western members from the main body of the "Institute, the appropriation available for the purpose of defraying "the ordinary expenses of this branch be increased from twenty-"five to forty per cent. (25 to 40%) of the fees of members in good "standing enrolled as members of the branch, and that the money "so payable be remitted to the credit of the Western Branch in "quarterly instalments, for disbursement under the direction of "the council of the branch."

MR. N. MACDONALD:—A suggestion has been made that the mining companies should be requested to assist the different branches. I seriously object to that proposal. If we cannot support ourselves without such assistance, then we have no right to exist at all.

Mr. Coste's motion was then put to the meeting and carried unanimously.

THE PRESIDENT:—I am sure the Council will now know the views of the membership at large. The question has already been considered by the Council, and I do not think after what has been said to-day that we need any definite instructions in dealing further with it.

PRESENTATION OF PRESIDENT'S GOLD MEDAL.

The President here presented the "President's Gold Medal" to Mr. Harry H. Yuill, of McGill University, for his paper entitled "The White Bear Mine, Rossland, B.C.," awarded the first prize in the "Student Members' Competition, 1908."

Mr. Yuill made an appropriate reply, in the course of which he referred in an appreciative manner to the generous treatment and encouragement afforded mining students by the Institute.

ELECTIONS OF COUNCIL, 1909.

There being no competition for vacant offices on the council for the ensuing year, the Secretary was instructed to cast one ballot and reported the following gentlemen duly elected:—

President—Dr. Willet G. Miller, Toronto, Ont.

Vice-Presidents—Dr. A. E. Barlow, Montreal, Que.; Mr. J. Obalski, Quebec, Que.

Councillors—Mr. R. W. Brock, Ottawa, Ont.; Mr. J. Stevenson Brown, Montreal, Que.; Mr. Thos. Cantley, New Glasgow, N.S.; Mr. C. J. Coll, Stellarton, N.S.; Mr. John Donnelly, Kingston, Ont.; Mr. E. L. Fraleck, Cobalt, Ont.; Mr. H. E. T. Haultain, Toronto, Ont.; Dr. Milton L. Hersey, Montreal, Que.; Mr. A. B. W. Hodges, Grand Forks, B.C.; Dr. J. Bonsall Porter, Montreal, Que.

Wednesday Afternoon Session.

The session opened at 3 o'clock, when Mr. J. McLeish, Statistician of the Federal Department of Mines, Ottawa, presented the following statistical returns:—

The Mineral Production of Canada in 1908.

For some years past the Department of Mines has succeeded in preparing a preliminary estimate of the minerals of Canada during the calendar year, in time for publication previous to, or for presentation at the Annual Meeting of the Institute during the first week of March, and, now following this custom, I am very glad indeed to be able to present to members of the Canadian Mining Institute some statistics of mining in Canada in 1908.

A preliminary review of the mineral production in Canada in 1908 shows a total mineral output valued at slightly over 87 million dollars, as compared with a little less than 87 million dollars in 1907.

The production in 1908 is made up of a little over 41½ million dollars in metallic ores and products; a little less than 32½ million dollars in non-metallic products (excluding the structural materials), and a little over 12¾ million dollars in structural material and clay products.

Details of the production in 1908 are shown in the following table:—

Nova Scotia	$ 14,262,958
New Brunswick	671,706
Quebec	6,445,393
Ontario	31,028,959
Manitoba	1,000,075
Saskatchewan	495,314
Alberta	6,201,718
British Columbia	23,556,425
Yukon, N.W. Territories	3,661,301
	$ 87,323,849

Details of the production in 1908 are shown in the following table:—

PRELIMINARY REPORT ON THE MINERAL PRODUCTION OF CANADA IN 1908.

(Subject to revision).

Product		Quantity (*a*)	Value (*b*)
METALLIC			$
Copper (*c*)	Lbs.	64,361,636	8,500,885
Gold	"	.....	9,559,274
Pig iron from Canadian ore (*d*)	Tons	99,420	1,664,302
Lead (*e*)	Lbs.	45,725,886	1,920,487
Nickel (*f*)	"	19,143,111	8,231,538
Cobalt	"	1,853,286	112,253
Silver (*g*)	Ozs.	22,070,212	11,667,197
Total value, metallic		.....	41,655,936

(*a*) Quantity of product sold or shipped.

(*b*) The metals, copper, lead, nickel and silver are for statistical and comparative purposes valued at the final average value of the refined metal in New York. Pig iron is valued at the furnace and non-metallic products at the mine or point of shipment.

(*c*) Copper contents of ore, matte, &c., at 13.208 cents per pound.

(*d*) The total production of pig iron in Canada in 1908 was 630,835 short tons valued at $8,111,194, of which it is estimated about 99,420 tons valued at $1,664,302 should be attributed to Canadian ore, and 531,415 tons valued at $6,446,892 to the ore imported.

(*e*) Lead contents of ore, matte, &c., at 4.200 cents per lb.

(*f*) Nickel contents of matte shipped at 43 cents per lb.

(*g*) Silver contents of ore, &c., at 52.864 cents per lb.

PRELIMINARY REPORT ON THE MINERAL PRODUCTION OF CANADA IN 1908.—*Con.*

(Subject to Revision).

Product		Quality	Value
			$
NON-METALLIC			
Arsenic	Tons	699	38,054
Asbestos	"	65,534	2,547,507
Asbestic and asbestic sand	"	25,239	25,829
Calcium carbide	"	6,864	417,150
Chromite	"	7,225	82,008
Coal	"	10,904,466	25,567,235
Corundum	"	1,039	100,389
Feldspar	"	7,877	21,099
Graphite	"	251	5,565
Grindstones	"	3,843	45,128
Gypsum	"	340,964	575,701
Limestone for flux in iron furnace	"	418,661	289,705
Magnesite	"	120	840
Mica	"	.....	191,602
Mineral pigments—			
Barytes	"	4,091	18,265
Ochres	"	4,746	30,440
Mineral waters	"	.....	109,391
Natural gas (*h*)	"	.....	1,012,060
Petroleum (*i*)	Bbls.	527,987	747,102
Phosphate (apatite)	Tons	1,596	14,794
Pyrites	"	47,336	224,824
Quartz	"	27,134	32,277
Salt	"	79,975	378,798
Talc	"	1,076	3,048
Tripolite	"	30	195
Total value, non-metallic		.....	32,479,006
			$
STRUCTURAL MATERIAL AND CLAY PRODUCTS			
Cement—natural	Bbls.	1,044	815
Cement—Portland	"	2,665,289	3,709,063
Flagstones	No.	4,000	3,600
Sand and gravel (exports)	Tons	298,954	161,387
Sewer pipe		.....	514,042
Clay products, stone, lime, &c., estimated		.....	8,500,000
Total structural material and clay products		.....	12,888,907
All other non-metallic		.....	32,479,006
Total value non-metallic		.....	45,367,913
Total value metallic		.....	45,655,936
Estimated value of mineral products not reported		.....	300,000
Total value, 1908		.....	87,323,849

(*h*) Gross return from sale of gas.

(*i*) Deduced from the amount paid in bounties and valued at $1.41½ per barrel.

As the production of 1908 shows a slight increase over that of 1907, the industry has therefore, in aggregate value, more than held its own, despite the very large decreases in the price of the metals ruling in 1908 as compared with those of 1907. This falling off in the values of the metals must have been a very serious matter for the metalliferous mines of the country. How serious it has been will, perhaps, be better realized when it is stated that had the four metals, copper, silver, lead and nickel maintained as high average prices in 1908 as in 1907, the total production in Canada in 1908 would have been worth over $8,000,000 more to the producers than was actually the case.

A comparison of average monthly prices of metals in 1907 and 1908, as quoted by the *Engineering and Mining Journal* of New York, showing the decreases in 1908 both in price and percentage is given hereunder:—

COMPARISONS OF PRICES OF METALS, 1907 AND 1908.

	1907	1908	Decrease in 1908	Percentage of Decrease
	Cts.	Cts.	Cts.	%
Copper	20.004	13.208	6.796	33.97
Lead	5.325	4.200	1.125	21.12
Nickel	45.	43.	2.	4.44
Silver	65.327	52.864	12.463	19.07
Spelter	5.962	4.726	1.236	20.73
Tin	38.166	29.465	8.701	22.79

The outstanding feature of the mining industry during the year has undoubtedly been the silver production, a total increase of over 72 per cent. being shown in the number of ounces produced. The metals copper and gold also show important increases in quantity produced, whilst iron, lead and nickel were produced in slightly smaller quantity than in 1907.

In the non-metallic class, decreases in gypsum and petroleum are more than counterbalanced by increases in coal, asbestos, natural gas, salt, &c. The Portland cement industry shows a small increase in sales and a large increase in quantity of cement made, with large stocks on hand at the close of the year.

The two following tables will illustrate these special features of increases and decreases more clearly, the first showing the total increases or decreases in value of some of the more important products, and the second the percentage increase or decrease in quantity as well as value:—

Product.	Increase	Decrease.
Copper		$2,806,484
Gold, Yukon	$ 450,000	
Gold, all other	726,494	
Pig iron, from Canadian ore		318,005
Lead		621,599
Nickel		1,303,869
Silver	3,318,538	
Asbestos	62,739	
Chromite	9,107	
Coal	1,185,393	
Gypsum		71,213
Natural gas	197,028	
Petroleum		309,986
Portland cement		68,265
Pyrites	12,333	
Salt	36,483	

Product.	Quantity.		Value.	
	Increase.	Decrease.	Increase.	Decrease.
Metallic—	%	%	%	%
Copper	13.86			24.82
Gold	14.03		14.03	
Pig iron (from Canadian ore only)		7.60		16.04
Pig iron (from home and imported ore)		3.24		11.11
Lead		4.22		24.45
Nickel		9.66		13.67
Silver	72.69		39.75	
Non-metallic—				
Asbestos and asbestic	0.38		2.73	
Coal	5.21		5.27	
Feldspar		37.40		29.27
Gypsum		29.83		11.01
Natural gas			24.00	
Petroleum		33.07		29.32
Salt	10.01		10.66	
Portland cement	9.41			1.81

While the production of copper shows an increase of nearly 14% in number of pounds produced, the total value of the production shows a decrease of nearly 25%. Also, while silver shows the number of ounces obtained to have been nearly 73% greater than in 1907, the total value is increased by less than 40%.

Portland cement, too, shows an increased quantity of sales of 9%, but a decrease in value of nearly 2%. This is but another way of illustrating the lower prices ruling in 1908.

Reviewing some of the more important mineral products in detail, we shall refer first to gold:—

Gold:—For the first time in nine years the gold output shows an increase over the previous year. The Yukon output in 1908 is estimated at about $3,600,000 as compared with $3,150,000 in 1907, while a considerably increased production is also shown in the province of British Columbia, derived chiefly from the Trail Creek ores, the placer workings having shown a smaller output.

In Nova Scotia, the output in 1907 was $282,686. Complete returns are not yet available for 1908, but the output was probably not over $225,000.

Of the total gold output in 1908, over 44 per cent. was obtained from placer and hydraulic workings and 56 per cent. from sulphuret and quartz ores.

Silver:—The estimated silver production of Canada in 1908 was 22,070,212 ounces, shipped as fine bars, silver bullion, and obtained in matte, ore, etc., as compared with 12,779,799 ounces produced in 1907, an increase of over 72 per cent. Owing, however, to the much lower price received in 1908, the total value shows an increase of only 40 per cent. Over 87 per cent. of the output was obtained from Ontario, and the increase is all to be credited to this province, since there was a slight falling off in the silver output of British Columbia.

The price of refined silver varied between a maximum of 57 cents on the 8th January and a minimum of 47⅝ cents on the 2nd of December, the average monthly price being 52.864 cents per ounce, as compared with 65.327 cents in 1907.

The output from the Cobalt district, in the province of Ontario, again shows a very large increase over the previous year, nearly twice as much silver having been produced. Returns from 29 shipping mines show the ore and concentrates shipped, as approx-

imately 25,497 tons, containing 19,296,430 ounces of silver as compared with 14,644 tons containing 9,982,363 ounces in 1907. Valued at the average price of refined silver for the year, the production in 1908 would be worth $10,200,865 and it represents an average return of 756 ounces of silver or $400 per ton of ore shipped, as compared with an average return of 681 ounces of silver, or $445 per ton of ore, shipped in 1907.

If the output of this district continues to increase at the present rate, Canada will in the immediate future, become one of the chief silver producing countries of the world. The total silver production of the world in 1907 was approximately 193 million ounces, the chief contributing countries being, Mexico 65 million ounces, United States 59 million ounces, Australia 17 million ounces, Canada nearly 13 million ounces, Germany 12 million ounces. With an output of 22 million ounces in 1908, Canada probably moves up to third place, but still does not produce more than from 10 to 12 per cent. of the world's output.

Copper:—Statistics of copper production in 1908 show a total output of 64,361,636 lbs., an increase of over 14 per cent. over the production of 1907. There was an increase of over 900,000 lbs. in the copper from the Sudbury mines, while preliminary statistics of production in British Columbia appear to show a very important increase in production in that province of over 7,000,000 pounds.

The New York price of electrolytic copper varied but slightly during the year, the lowest being 12 cents in February and the highest 14¼ cents in December, the average for the year being 13.208.

The total exports of copper in ore, matte and blister, being, according to Customs Department returns, 25,568 tons.

Lead:—All of the lead production shown in the general table, viz.: 45,725,886 pounds valued at $1,920,487 was obtained in the province of British Columbia. The production in 1907 was 47,738,703 pounds, valued at $2,542,086, a decrease in quantity being therefore shown of about 4 per cent.

The total amount paid as bounty on lead production was, during the twelve months, $139,064.57.

The exports of lead in ore, etc., during the year were 2,256 tons, and of pig lead 6,971 tons or a total of 9,227 tons.

The price of lead in New York during the year varied between 3.60 and 4.60 cents, averaging about 4.2 cents per pound.

Nickel:—With the exception of the nickel contained in the ores shipped from the Cobalt district, the production of nickel in Canada is derived entirely from the well-known nickel-copper deposits of the Sudbury district. Previous to 1906 the output had been increasing steadily for a number of years. During the past three years, however, the production has not varied very greatly. About 815 tons less matte was shipped in 1908 than in 1907. The nickel contents were also somewhat lower in 1908, averaging about 45.1 per cent. as compared with 48.1 per cent. in 1907. On the other hand the copper contents were higher in 1908.

Two companies are carrying on active operations: The Mond Nickel Co., at Victoria Mines, and the Canadian Copper Co., at Copper Cliff. The ore is first roasted and then smelted to a Bessemer matte containing from 77 to 80 per cent. of the combined metals, copper and nickel, which is shipped to the United States and Great Britain for refining.

The following were the aggregate results of the operations on the nickel-copper deposits of Ontario in 1906, 1907 and 1908:—

——	1906 Tons of 2,000 lbs.	1907 Tons of 2,000 lbs.	1908 Tons of 2,000 lbs.
Ore mined	343,814	351,916	409,551
Ore smelted	340,059	359,076	360,180
Bessemer matte produced	20,364	22,041	21,197
" " shipped	20,310	22,025	21,210
Copper contents of matte shipped	5,265	6,996	7,503
Nickel " "	10,745	10,595	9,572
Spot value of matte shipped	$4,628,011	$3,289,382	$2,930,989
Wages paid	1,117,420	1,278,694	1,286,265
Men employed	1,417	1,660	1,690

According to Customs returns exports of nickel in matte, etc., for the twelve months ending December 31, were as follows:—

	1906	1907	1908
	Pounds.	Pounds.	Pounds.
To Great Britain	2,716,892	2,518,338	2,554,486
To United States	17,936,953	16,857,997	16,865,407
	20,653,845	19,376,335	19,419,893

The price of refined nickel in New York, was quoted during the first nine months at from 45 to 50 cents per pound and during the balance of the year from 40 to 45, cents according to size and terms or order.

The above figures do not include the nickel contents of the silver-cobalt ores from the Cobalt district, of which it is difficult to obtain satisfactory returns. The shippers of silver-cobalt ores receive little or no return for the nickel contents, although this metal forms an important constituent of the ore.

Iron Ore:—The total shipments of iron ore from mines in Canada in 1908 were 203,490 short tons, valued at the mine at $486,857 as compared with 312,496 tons valued at $666,941 in 1907. The greater part of this production was from the Helen mine, Michipicoten, delivered to Midland and Hamilton. During 1908 very little Canadian ore was exported.

Pig Iron:—The total production of pig iron in Canada in 1908, from both Canadian and imported ores, according to direct returns from nine plants comprising 16 furnaces, was 630,835 short tons valued at $8,111,194 as compared with 651,962 tons valued at $9,125,226 in 1907. These figures do not include the output from the two electric furnace plants, making ferro-products, which are situated at Welland, Ontario, and Buckingham, Quebec. Of the total output of pig iron during 1908, 6,709 tons, valued at $171,383 were made with charcoal as fuel and 624,126 tons valued at $7,939,811 with coke.

The amount of Canadian ore, including mill cinder, &c., used was 219,266 tons while the quantity of imported ore was 1,051,445 tons. The total amount of coke used during the year was 817,746 short tons valued at $1,770,320. The total amount of charcoal used was 1,121,990 bushels valued at $85,738. The quantity of limestone flux charged was 483,065 tons.

The plant of the Atikokan Iron Co., Ltd., was out of commission throughout the year, while a number of others were operated for a part of the year only. The blast furnace at Londonderry was in blast for little over a month and the furnace of the Deseronto Iron Co., Ltd., for about two months.

Steel:—The returns for the year from eight companies making steel showed a total output of ingots and castings of 588,763 short tons, valued at $9,233,602, as compared with 706,982 tons, valued at $15,612,590, from seven companies in 1907.

These figures are made up as follows:—

	1907		1908	
	Tons.	$	Tons.	$
Ingots—Open hearth (basic)	459,240	9,157,703	443,442	6,001,277
Bessemer (basic)	225,989	4,293,791	135,557	2,535,287
Castings—Open hearth (acid and basic)	20,602	2,031,380	9,051	617,126
Other Steels	1,151	129,716	713	79,912
	706,982	15,612,590	588,763	9,233,602

Iron and Steel Bounties:—Following is a statement of the bounties paid on iron and steel during the calendar year, as kindly furnished by the Trade and Commerce Department:

——	1907		1908	
	Quantity on which Bounty was paid	Bounty	Quantity on which Bounty was paid	Bounty
	Tons	$ c.	Tons	$ c.
Pig iron, made from Canadian ore	95,914.97	201,421 47	101,647	213,458 34
Pig iron, made from imported ore	537,803.45	591,583 80	517,427	569,166 93
Total, pig iron	633,718.42	793,005 27	619,074	782,628 27
Steel ingots	666,589.87	1,099,873 37	556,289	917,876 63
Steel wire rods	68,738.22	412,417 26	49,630	297,778 68
Total bounty paid on iron and steel		2,305,295 90		1,998,283 58

Asbestos:—Returns of shipments of asbestos from the Eastern Townships, province of Quebec, were received from twelve operating companies who employed 2,643 men in mine and mills and paid in wages $1,002,768. Several other companies were engaged in development work and preparing to make shipments during the coming year.

The total shipments divided into crude and mill stock were in 1907 and 1908 as follows:

	1907		1908	
	Tons	Value	Tons	Value
		$		$
Crude	4,327	830,633	3,346	692,232
Mill stock	57,803	1,654,135	62,188	2,855,275
Total asbestos	62,130	2,484,768	65,533	2,547,507
Asbestic and asbestic sand	28,296	20,275	25,239	25,829
Total products	90,426	2,505,043	90,772	2,573,306

Exports of asbestos, according to Customs returns, were:

	Tons	Value
		$
Twelve months ending December, 1906	59,864	1,689,257
" " " " 1907	56,753	1,669.299
" " " " 1908	61,210	1,842,763

Coal and Coke:—Each of the coal mining provinces, except British Columbia, contributed an increased output to the coal production of Canada in 1908. The total sales and shipments of coal, including colliery consumption and coal used in making coke, were 10,904,466 short tons, an increase of about 5 per cent. as compared with 1907. Of the total, Nova Scotia contributed over 59 per cent., Saskatchewan and Alberta over 19 per cent. and British Columbia 21 per cent.

The production by provinces was approximately as follows, the figures, of course, being still subject to correction:

Province	1907		1908	
	Tons of 2,000 lb.	Value	Tons of 2,000 lb.	Value
		$		$
Nova Scotia	6,354,133	12,764,999	6,539,866	13,138,124
New Brunswick	34,584	77,814	60,000	135,000
Saskatchewan	151,232	252,437	130,000	214,500
Alberta	1,591,579	3,836,286	1,845,000	4,899,611
British Columbia	2,364,898	7,390,306	2,329,600	7,280,000
Yukon	15,000	60,000	*	*
Total	10,511,426	24,381,842	10,904,466	25,567,235

The total production of oven coke in 1908 was approximately 865,257 short tons, valued at $3,668,974, being an increase of about 3 per cent. over the quantity produced in 1907. The coke was made in the provinces of Nova Scotia, Alberta and British Columbia and entirely from Canadian coal. At the end of the year, there were in Nova Scotia about 659 ovens in operation and 173 idle, and in Alberta and British Columbia, on the same date, 916 in operation and 528 idle, not including the ovens at Hosmer and Comox in British Columbia, from which no returns have yet been received.

Petroleum and Natural Gas:—The production of crude petroleum is, as usual, practically all derived from the Ontario peninsula. Direct returns from the producers have not been obtained, but the production has been estimated on the basis of the bounty of 1½ cents per gallon paid by the Dominion Government. The total bounty paid in 1908 was $277,193.21, representing a production of 527,987 barrels, compared with a bounty of $414,157.89 paid in 1907, representing a production of 788,872 barrels. A decreased production of 33 per cent. is, therefore, shown.

Natural gas was produced in the counties of Welland, Haldimand, Norfolk, Kent, Essex and Bruce, in Ontario, and at Medicine Hat, Alberta; the sales from the Ontario fields constituting over 95 per cent. of the total.

*No production reported.

The total receipts from gas sold in 1908 show an increase of about 24 per cent. over the receipts of 1907 and are now larger than at any time since the gas was first used.

Portland Cement:—Complete statistics of cement production in 1908 have been received from twenty-three operating plants.

The total quantity of cement made was 3,495,961 barrels, as compared with a total 2,491,513 barrels made in 1907, showing an increase of 1,004,448 barrels or over 40 per cent.

The total sales were 2,665,289 barrels, as compared with 2,436,093 barrels in 1907, an increase of 229,196 barrels or over 7 per cent. The total daily capacity of the 23 plants was about 27,500 barrels, as compared with an operating capacity of 14,300 barrels 1907. The operating plants were distributed as follows:—One each in Nova Scotia, British Columbia and Manitoba, (the latter manufacturing a natural Portland), two in Alberta, three in Quebec province and 15 in Ontario.

Of the 23 operating plants, twelve use marl and clay, ten use limestone and clay, and one, blast furnace slag.

Detailed statistics of production in 1907 and 1908 are as follows:—

	1907	1908
	Barrels	Barrels
Portland cement sold	2,436,093	2,665,289
" manufactured	2,491,513	3,495,961
Stock on hand, January 1	299,015	383,349
" " December 31	354,435	1,214,011
Value of cement sold	$3,777,328	$3,709,063
Wages paid	956,080	1,274,638
Men employed	1,786	3,029

The average price per barrel at the works in 1908 was $1.39, as compared with $1.55 in 1907.

The imports of Portland cement into Canada during the 12 months ending November, 1908, were 1,600,934 cwt. valued at $530,209.

This is equivalent to 457,408 barrels of 350 pounds at an average price per barrel of $1.16. The imports in 1907 were equivalent to 672,630 barrels valued at $837,520 or an average price per barrel of $1.24½. The duty is 12½ cents per hundred pounds.

There is very little cement exported from Canada, the consumption is, therefore, practically represented by the Canadian sales together with the imports.

Following is an estimate of the Canadian consumption of Portland cement for the past five years:—

Year	Canadian	Imported	Total
	Barrels	Barrels	Barrels
1904	910,358	784,630	1,694,988
1905	1,346,548	917,558	2,264,106
1906	2,119,764	694,503	2,814,267
1907	2,436,093	672,630	3,108,720
1908	2,665,289	457,408	3,122,697

DR. WOODMAN:—I should like to ask Mr. McLeish what is his basis in estimating the value of the production of coal.

MR. MCLEISH:—In so far as coal is concerned we have endeavoured to value the production at the selling price as far as ascertainable, but it is practically impossible to obtain these values from all of the operating companies. The result is that in many cases we have been compelled to estimate values. In the case of Nova Scotia I think the total production was valued at $2.25 per long ton, which in the absence of definite statistics is merely an estimate of the possible average selling price of the coal.

MR. J. C. MURRAY:—Has anything been done in the direction, suggested at the last meeting, of standardizing the various methods of computing mineral statistics?

MR. MCLEISH:—I am not aware that anything has been done officially with reference to securing more uniform methods of valuation in our mining statistics. Last year I had opportunities of discussing this subject very briefly with the heads of the Mining Bureaus in most of the provinces and I can say that they are all

very willing to confer and endeavour to arrive at a more uniform basis of valuation; but so far as any definite scheme of getting together is concerned, I am not aware of anything having been done.

THE PRESIDENT:—I will now ask Mr. Obalski to present the statistics of production of the province of Quebec.

MINERAL OUTPUT OF QUEBEC IN 1908.

MR. OBALSKI:—The returns submitted by Mr. McLeish for the province of Quebec show a valuation of one million dollars in excess of my own estimate, which is as follows:

Minerals	Quantities Shipped or Used (Tons of 2,000 lbs.)	Gross Value
Bog iron ore	11,628	$ 30,957
Calcined ochre	1,346	15,440
Raw ochre	1,500	4,500
Chrome iron	7,564	83,740
Copper ore	26,598	159,588
Asbestos	65,156	2,551,596
Asbestic	24,011	34,666
Mica, trimmed	106	95,311
Phosphate of lime	175	1,610
Prepared graphite	2,640 lbs.	165
Magnesite	65 tons	520
Slates (squares)	4,336	20,056
Flagstones	4,000 square yards.	3,600
Cement (barrels)	801,695	1,127,335
Granite	30,000 cubic yards	250,000
Lime	556,000 bushels	96,000
Bricks	94,000,000	525,000
Tiles and Pottery		270,000
Limestone	97,710 cubic yards	223,580
		$5,493,664

6,324 men employed in the mining industry of the province of Quebec, receiving $2,094,357.00 in wages.

The production of chrome has been as follows:—

2nd class, in lumps	3,754	gross tons, value	$38,740
Concentrated	3,000	" "	$45,000
	6,754		$83,740

The production of asbestos, was as follows (2,000 lb. tons):—

1st class, crude	900 tons.		$261,216
2nd class, crude	2,771 "		438,305
Fibre	13,911 "		716,811
Paper stock	47,574 "		1,135,264
	65,156		$2,551,596
Asbestic	24,011		34,666

Pig Iron.—There was manufactured during the year, 5,989 gross tons of charcoal pig iron, valued at $171,286.00.

The above figures show the value of the product at the mine or at the nearest shipping point.

MR. FRITZ CIRKEL.—Mr. Obalski refers to the production of magnesite in his report. May I ask him to give us some particulars concerning these deposits in the province. I have seen samples of magnesite from the Calumet district, but they did not appear to be of standard quality.

MR. OBALSKI.—The magnesite I referred to, came from a locality distant about fourteen miles from Calumet station, Granville county. The property was purchased from the government and opened last year. The production last summer was about two hundred tons, which was partly used in Montreal, I understand. There is also a fair market for the product in the United States. It is shipped in the raw state. They are using it extensively for refractory bricks at Pittsburg, and for carbonic acid manufacture it is in general use. It contains about 50 per cent. of carbonic acid. The quality of our Quebec product compares favourably with Grecian and Austrian magnesite, and the company expect to make large shipments during the present year.

MR. CIRKEL.—About what is the price at the present time? About six or seven dollars?

MR. OBALSKI.—About that, but after it has been calcined it is worth from twenty-five to thirty dollars.

THE SECRETARY.—Mr. Jacobs, Secretary of the Western Branch, has sent me some figures on the mineral production of British Columbia in 1908, based chiefly upon information obtained from those in charge of important mines in the province. The

figures, of course, are subject to revision, but are believed to be rather under than overstated.*

ESTIMATED VALUE OF MINERAL PRODUCTION, BRITISH COLUMBIA, 1908.

	1908	Changes
Gold, placer	$ 682,000 D	$ 146,000
Gold, lode	5,291,520 I.	1,236,500
Total gold	$5,973,520 I.	$1,090,500
Silver	1,518,500 D.	185,325
Lead	1,654,695 D.	636,763
Copper	5,792,820 D.	2,373,724
Zinc and iron	280,000 I.	229,400
Total	$15,219,535 D.	$1,875,912
Coal	5,950,000 D.	$350,235
Coke	1,488,000 I.	150,522
Building materials, etc.	1,200,000 I.	50,600
Total	$8,638,000 D.	$149,113
Summary:		
Metalliferous	$15,219,535 D.	$1,875,912
Non-metalliferous	8,638,000 D.	149,113
Total mineral production	$23,857,535 D.	$2,025,025

MINERAL PRODUCTION, BRITISH COLUMBIA, 1907–1908.

	1907	1908	Changes
Gold, placer, oz.	41,450	34,100 D.	7,350
Gold, lode, oz.	196,179	256,000 I.	59,821
Total gold	237,629	290,100 I.	52,471
Silver, oz.	2,745,448	3,037,000 I.	291,552
Lead, lb.	47,738,703	43,775,000 D.	3,963,703
Copper, lb.	40,832,720	43,885,000 I.	3,052,280
Coal, long tons	1,800,067	1,700,000 D.	100,067
Coke, long tons	222,913	248,000 I	25,087

*The official returns of the Department of Mines of the Province, since published, are as follows: Placer gold, $647,000; lode gold, $5,282,880; silver, $1,321,483; lead, $1,632,799; copper, $6,240,249. Total value of minerals produced (including coal), $23,851,277.

MINERAL PRODUCTION OF BRITISH COLUMBIA BY DISTRICTS AND DIVISIONS, 1907–1908

Name	Divisions		Districts	
	1907	1908	1907	1908
CARIBOO DISTRICT			$360,500	$420,000
Cariboo	$306,500	$350,000		
Quesnel	44,000	50,000		
Omineca	10,000	20,000		
CASSIAR DISTRICT			572,809	225,000
EAST KOOTENAY DISTRICT			5,548,880	4,726,060
WEST KOOTENAY DISTRICT			4,792,976	5,710,690
Ainsworth	364,868	624,000		
Nelson	614,395	414,984		
Slocan	619,842	779,740		
Trail Creek	3,049,702	3,725,142		
Other parts	144,169	166,824		
LILLOOET DISTRICT			15,721	5,000
YALE DISTRICT			8,444,326	7,160,245
Osoyoos, Grand Forks and Greenwood	8,354,995	6,994,925		
Similkameen	56,564	135,000		
Yale	32,767	30,320		
COAST DISTRICTS			6,147,348	5,610,540
Totals			$25,882,560	$23,857,535

* The districts are shown in the order followed in the official reports of the provincial Bureau of Mines. Similarly, Rossland is included in the Trail Creek, and Greenwood and Grand Forks mining divisions, which constitute the district generally known in the province as the Boundary, are shown as in the Yale district, as is customary in the official publications. The decrease shown against Cassiar district is partly the result of the transfer of a portion of Skeena mining division to the coast district, while that of Lillooet is the result of a temporary stoppage of dredging on that part of the Fraser river.

COMPARATIVE TABLE.

To facilitate comparison with other recent years, the following table, showing amount and value of the mineral products of the province for the years 1905, 1906, 1907, respectively, taken from the "Annual Report of the Minister of Mines for British Columbia for 1907," is appended:—

	1905		1906		1907	
	Quantity	Value	Quantity	Value	Quantity	Value
		$		$		$
Gold, placer....oz.	48,465	969,300	47,420	948,400	41,400	828,000
Gold, lode.....oz.	238,660	4,933,102	224,027	4,630,639	196,179	4,055,020
Total gold...	287,125	5,902,402	271,447	5,579,039	237,579	4,883,020
Silver.....oz.	3,439,417	1,971,818	2,990,262	1,897,320	2,745,448	1,703,825
Lead.....lb.	56,580,703	2,399,022	52,408,217	2,667,578	47,738,703	2,291,458
Copper.....lb.	37,692,251	5,876,222	42,990,488	8,288,565	40,832,720	8,166,544
Total metalliferous.....		16,149,464		18,432,502		17,044,847
Coal, tons (2,240lb	1,384,312	4,152,936	1,517,303	4,551,909	1,800,067	6,300,235
Coke " "	271,785	1,358,925	199,227	996,135	222,913	1,337,478
Other minerals (building materials, etc.)....		800,000		1,000,000		1,200,000
Total production.		22,461,325		24,980,546		25,882,560

NOTE.—There was a comparatively small production of iron and zinc included in the amounts shown for "other minerals" in the foregoing table.

ONTARIO'S MINERAL PRODUCTION IN 1908.

THE PRESIDENT.—Gentlemen, Mr. T. W. Gibson, the Deputy Minister of Mines for Ontario, has not found it possible to be present with us at this meeting, but he has sent me a brief statement of the mineral production of Ontario for 1908, which I will read to you:—

VALUE OF THE MINERAL PRODUCTION ONTARIO, 1908, ESTIMATED ON A "REFINED VALUE" BASIS.

	Quantity	Price	Value
Gold.....	3,465 oz.	.....	$ 60,337
Silver.....	19,424,781 "	52.864c.	10,278,716
Cobalt.....	1,224 tons.	75c. lb.CaO	2,334,175
Nickel.....	10,175 "	40c. lb.	8,140,000
Copper.....	7,561 "	13.208c.lb.	1,994,672
Iron ore.....	199,395 "	.....	537,379
Pig Iron.....	271,656 "	.....	4,390,839
			$27,736,118
Less Ontario Iron Ore (170,215 tons) into smelted pig iron.....			456,176
			$27,279,942
Add value non-metallic products.....			8,513,962
			$35,793,904

Mr. Gibson was not able to complete these statistics until within a few days ago, chiefly for the reason that many large and rich shipments from Cobalt are sent to a distance and definite returns are not received for some time after shipment.

The silver production, meanwhile, has somewhat exceeded anticipations, Cobalt having produced 19,424,781 ounces, and the camp may now be regarded as the largest producer of silver in the world. This production is derived from an area not more than six square miles in extent but it is nearly equivalent to the output of any two States in the American Union (Applause). The largest silver production of any one State is that of Montana, which is 11,000,000 ounces, in comparison with Cobalt's 19,000,000 ounces. Mr. Gibson has valued this silver at 52.08 cents an ounce. At that valuation the silver shipped from Cobalt would be worth $10,278,716. The price of cobalt has considerably decreased. It is estimated here at 75 cents per pound, whereas two or three years ago cobalt oxide was worth from $2.00 to $2.50 per pound; nickel is valued at 40 cents a pound, the value of our Ontario production being $8,140,000.

MR. MCLEISH:—What value has been placed on the iron output?

THE PRESIDENT:—$2,234,175. Mr. Gibson has deducted from his total the sum of about $500,000 to represent the value of Ontario iron ore smelted into pig iron.

MR. GEO. R. SMITH:—Will Mr. McLeish inform us what proportion of the production of nearly $10,000,000 of gold came from the Yukon.

MR. MCLEISH:—$3,600,000.

MR. TYRRELL:—Is that for 1908?

MR. MCLEISH:—Yes. The Interior Department values the gold for the purposes of collecting the royalty at $15, but I think that an average for a number of years would place the value of the gold at approximately $16.60.

MR. COSTE:—It seems to me, Mr. President, that the necessity of something being done to standardize the methods of compiling mineral statistics has never been brought more forcibly before this Institute. Here is one province showing returns of a million dollars less and another province four million dollars more than the Dominion Government returns! Surely this is an

absurd state of affairs; and when you come to present this conflicting information to outside capitalists, and to the public, what are they to understand by it? It seems to me that it is the duty of the Dominion Department of Mineral Statistics to take the necessary steps for the standardization of methods of compilation. It is most important in the interests of the mining industry and community in general that this should be done. (Hear, hear!). I don't know whether we should approach the subject again by way of a resolution or not, but certainly something ought to be done.

The President:—I don't know that the matter is as serious as it appears at first sight, since in these several statements the different methods of arriving at results are clearly stated. For example in Mr. Gibson's brief statement, which I have read, he has told us that his valuation is based on the selling price of the metals. Of course Mr. Gibson's ordinary method of computing mineral statistics is somewhat different from that, but this particular report merely shows the values of the refined products.

Mr. Coste:—But, Mr. President, if such explanations are necessary, do they not indicate the weakness of the case? *Qui s'excuse, s'accuse.*

Wednesday Evening.

At eight o'clock an interesting lecture and demonstration was given by Prof. Alfred Stansfield, in the lecture theatre of the Chemistry and Mining building, McGill University, on the subject of "The Electric Furnace with special reference to the Electrometallurgy of Steel." The lecture was well attended and was highly appreciated.

Thursday Morning Session.

The meeting was called to order at 10.30 o'clock by the President, who said: We are honoured by the attendance at this meeting of a number of distinguished gentlemen from the United States, including representatives of the Geological Survey and of some of the great universities. Mr. S. F. Emmons and Mr. Waldemar Lindgren, of the United States Geological Survey, have kindly undertaken to address us this morning. I have, therefore, much

pleasure in introducing to you Mr. Emmons and Mr. Lindgren, the former of whom will speak on the subject of "Economic Geology in the United States."

MR. EMMONS thereupon delivered a most interesting address* which was listened to with marked attention. At the close of the address the President said:

I am sure we are all very grateful to Mr. Emmons for his extremely instructive address. We, in Canada, feel that we can learn much from the experience of the United States in mining matters. It is very fortunate for us that, with our vast undeveloped territory, we have the advantage of information such as has been made available by the U. S. Geological Survey. Their literature is almost as valuable to us as it is to them, and I can only say that we are more than pleased that Mr. Emmons should have given us this historical review of the progress of economic geology since the establishment of the United States Survey.

DR. ADAMS:—It gives me very great pleasure, indeed, to express my sincere appreciation of this valuable paper of Mr. Emmons, giving as it does a historical resumé of the opinions held by the geologists of the United States Survey, as the work of investigation gradually proceeded. The economic geologists of the United States Geological Survey have been more prominent in the development of the knowledge of our ore deposits than probably any other body of men in the world, and I consider Mr. Emmons' paper is, in this way, of great value in presenting concisely their opinions and the causes which have led to those opinions during the development of the very important work of this survey. On my own behalf and on behalf of the Canadian Mining Institute I desire to thank Mr. Emmons for his presence on this occasion and for his extremely illuminating paper.

THE PRESIDENT:—I have now much pleasure in asking Mr. Waldermar Lindgren of the United States Geological Survey to address you.

MR. LINDGREN then delivered an address on the subject of "Metallogenetic Epochs."†

*See Page 89
†See Page 102

THE PRESIDENT:—I am sure that the publication of Mr. Lindgren's address in our transactions will prove of great value and interest to the members of the Institute. This paper will remind us from year to year of his kindness in coming from Washington to attend this meeting. We have a number of gentlemen present who are "strong" on the igneous theory, and I am sure we are all specially glad that we have with us to-day Professor Kemp of Columbia University. (Applause). I would ask Professor Kemp to address the meeting.

PROF. KEMP:—I am growing to feel very much at home at the meeting of the Canadian Mining Institute (hear, hear!). It seems as if it were hardly proper for the spring to go by without my crossing the invisible line, which we call the border, to attend the annual session of the Canadian Mining Institute.

The subjects that have just been presented are, of course, of great interest to us all. Those of us who started a few years after Mr. Emmons began his work, and whose early studies were very largely guided by his extremely careful and impressive writings, always delight to hear him speak about the earlier as well as the later years of the work of the Geological Survey (Applause). I do not know that any one else could so carefully and accurately, and so largely on the basis of personal experience, trace the course of our survey through the changes which it has experienced; and while we owe Mr. Emmons a very great debt for his scientific contributions, I think we ought not to forget that many of us have been equally interested by the careful literary finish which his writings always display. (Applause).

Mr. Lindgren's paper sums up for us those large generalizations that always set us thinking, and whatever views we may have upon the general origin of ores, they must fall in with the large facts. The ore deposits were formed with particular abundance especially at geological times which are rather sharply defined, and if our other views do not coincide or fit in with these great sweeping facts, which we can observe in the field, then they must give way in favour of others that do.

While, like most of us in later years, I have been particularly impressed with the coincidences presented by the eruptive outbreaks and ore-formation, like others I have endeavoured not

to be unduly carried away by the force of these considerations. Yet we must admit, willingly or unwillingly, that for the vast number of our ore deposits there is an extraordinary coincidence between their time of formation and the eruptive outbreaks which characterize that particular portion of the geological record. As Mr. Lindgren has summed up the different districts we see that the vein formation does go along with marked igneous outbreaks, and that the ores are largely associated with eruptive rocks. We cannot escape the influence and force of this association. (Applause).

MR. TYRRELL:—Mr. President, it is with a great deal of pleasure that I express my appreciation, and I think the appreciation of every member of the Institute present, of the two papers we have just heard from Mr. Emmons and Mr. Lindgren. (Applause). These two papers very adequately sum up our present knowledge of the ore deposits on this continent. It seems to me that they will form a basis to which we can henceforward refer for the knowledge that is at present possessed in regard to American ore deposits.

Mr. Lindgren's paper was particularly interesting to Canadians as affording them some idea of what ores have been found in the various rocks of different ages in the United States and what similar rocks in Canada may be expected to produce. I think every member present must have had this idea in his mind when listening to the classification of the rocks of various ages on this continent. It would be a great step in advance for the economic geologist, if, instead of being obliged to think in the palæontologic scale, he could think in the mineraliferous or metallographic scale; in other words if he could think of the age or ages of the gold deposits or of the silver deposits, and so on, instead of being obliged to carry his mind back to the palæontologic scale which geologists at present use.

These are papers that we must read and think over very carefully. It would be rash to attempt to think that we had absorbed all the information they contain. For myself I know I did not retain one-fifth of the information contained in them, but I am sure every member present will read and study them with a great deal of interest and profit. (Applause).

PROF. BAKER.—I would like to express, on behalf of one branch of the technical training of the Dominion, our appreciation of the work of Mr. Emmons and Mr. Lindgren as well as that of Prof. Kemp—to express our appreciation of the work they have been doing on this side of the water. The researches of the European geologists, of course, excellent as they no doubt are, are unfortunately printed in languages with which the greater number of economic geologists of this country are not familiar. The works on the other hand, of such men as Mr. Emmons, Mr. Lindgren and Dr. Kemp, and other American geologists, are written in our own language. They, therefore, form part of our literature in the subject and from this standpoint as well as from the standpoint that they are "principles of geology" and therefore not restricted to specific ore deposits, they are as applicable to our deposits in Canada as they are to the deposits in the United States. Their work has, therefore, been of the greatest possible value to Canadians. Unfortunately, so far the economic study in Canada has been, as Mr. Emmons has pointed out to us, rather restricted, largely because of lack of funds available for this purpose in this country; but with the excellent guidance given to us by the descriptions of the work that has been done in the United States, we are advantageously equipped to study the economic geology of this country. For that reason I would like to convey to these gentlemen, and through them to their co-workers of the United States, my appreciation, which I am sure is shared by all economic geologists in Canada, of the excellent work they are doing in the United States. (Applause).

DR. ADAMS:—Mr. Chairman, I would like to add my testimony to that which has been given by the other speakers with reference to the merits of the papers which we have just heard. All members of the Canadian Mining Institute should take an interest in the question of the origin of our ore deposits and we should be especially grateful to these gentlemen who have come so far to speak to us on this important subject. There are no greater authorities in America than these three gentlemen from the United States, who are attending our meeting. When I went to the meeting of the American Geological Society at Baltimore last Christmas, with an authorization from the Council to invite these gentlemen to come here, I was greatly pleased at the readi-

ness with which they accepted the invitation to come to this far northern city in the middle of winter and speak to us on these subjects in which both they and we are so intimately concerned.

The paper which Mr. Lindgren has read is one of very great interest to us in Canada. It is the first time in which such a sharp definition has been given of the ages in which the concentration of the various metals took place, and the fact that it is possible to point out that all the mercury we have is practically of Post-Pliocene date, whereas the gold was very largely concentrated in the Tertiary times, is a generalization of extreme interest.

I feel that the Geological Survey of the United States is to be congratulated on the very free hand which it has given to Mr. Lindgren in the new arrangement made with him. In the United States survey, they are suffering from the same disease which afflicts our survey here in Canada, namely, the resignation of the economic geologists from their staff to accept positions with the great mining companies. In the case of Mr. Lindgren the Geological Survey at Washington is determined to retain his services and it has therefore arranged for him an almost unique position, in which he has full and free permission to go anywhere in the United States and study any ore deposits, more particularly with regard to the questions of origin and mode of occurrence, so that I think we in Canada will reap a marked benefit in the future from the increased opportunities for investigation thus given to Mr. Lindgren for research. (Applause).

MR. COSTE.—I wish also to express my appreciation and gratitude to Mr. Emmons and Mr. Lindgren for their presence here to-day, and for their most excellent papers.

I am very much pleased indeed that the two papers presented this morning came in the order in which they did, because they point out the great moral that in geological science, as well as in other sciences, our knowledge is increasing and that we are coming nearer and nearer to the fundamental truths. Mr. Emmons has shown us very plainly the different stages in the development of the opinion of geologists in the United States concerning the origin of ore deposits and the gradual acceptance of the theory of their—in the majority of instances—volcanic origin. Afterwards we had an extremely lucid paper from Mr. Lindgren, showing us to

what a vast extent our ore deposits are connected with vulcanism and volcanic disturbances and intrusions all over this continent and at various periods of the earth's history. Some of us have gone even further in Canada, and thus our American friends are also benefited by their visits here. As you all know I have pointed out during recent years a further illustration of this volcanic origin of ore deposits in the evident fact that the petroleum deposits, all over this continent, are also connected with and can be attributed to similar volcanic disturbances and emanations. If there are metallogenetic provinces (and Mr. Lindgren has proved that) there is no doubt that there are also petroliferous provinces, which are plainly indicated between the two great mountain ranges of North America, namely the Appalachian Mountains and the Rocky Mountains, or Cordillera system. What I mean is this:—The Appalachian oil fields follow in a belt along the Appalachian range for over 1,000 miles from Canada to Alabama, and millions upon millions of barrels of oil have been taken out along that belt, which is a fissured belt, the disturbances of which are connected with the uplift of the Appalachian range, and the oil is due to solfataric volcanic emanations which come up along the fissures of this dislocated belt. In the same way, in California, we have enormous oil fields (from which they obtained some 45 million barrels of oil last year) and these fields are also following there the Coast Range of mountains and are connected with the orogenic uplifts and volcanic emanations of that range. In the Northwest of Canada we are developing now, along the foot of the Rocky Mountain range, enormous deposits of natural gas, and I have no doubt oil will also be developed there. I shall present a paper on this subject at this meeting; but let me repeat, as Mr. Emmons has pointed out this morning, geologists are coming nearer and nearer to the theory of volcanic origin as the genesis of ore deposits. They do not, however, go far enough yet in that direction, as there is a good deal more that can be attributed, in the geological history of the world, to volcanic origin than what has been generally attributed to it, such as the origin of petroleum; and I am proud that some of us in Canada are in the vanguard and leading our Washington friends on the right path along this line of thought.

THE PRESIDENT.—We have another paper on the programme this morning, to be presented by Dr. A. C. Lane, State Geologist of Michigan. This paper also has a bearing on the formation of ore deposits. You will remember the story that in ancient times Moses struck the rock and brought forth water. Well, Dr. Lane is going to tell us what kind of water they struck in the deep mines of Michigan. (Applause).

Dr. Lane then read his paper, which he illustrated with lantern slides, on THE IRON MINES OF MICHIGAN AND THEIR MINE WATERS.

Mr. G. R. Mickle, Mine Assessor, of Toronto, Ont., then read a paper entitled "THE PROBABLE EFFECT OF THE ACREAGE TAX ON MINING LANDS IN ONTARIO." An interesting discussion followed, in the course of which the question of the Federal Mining Law was introduced by Lt.-Col. A. M. Hay, who said on this subject:—

THE FEDERAL MINING REGULATIONS.

I think this question of acreage taxation is embraced in the greater question of a complete revision of the Mining Act. (Hear, hear!). I think all these questions should be relegated to those who are going to deal with a new Mining Act for the whole Dominion, and the Institute should recommend to the Government the appointment of a Royal Commission to deal with the question. I do not think this Institute should be asked to appoint a committee to recommend legislation, which is to go to other people and be either turned down by one or swallowed by another. The Government ought to appoint a Royal Commission and pay the members handsomely, so that they could afford to neglect all other business in order to give Canada a Mining Act that every man can work under. (Applause).

DR. BARLOW.—The Institute should certainly take the initiative in this matter. At the present time the Dominion Mining Law is administered by the Department of the Interior, instead of, as properly, by the Department of Mines.

I think the Minister of Mines would welcome any suggestion from the Institute to the effect that the mining lands be admin-

istered by his Department; and would also support any effort put forward by the Institute towards securing a good mining law.

MR. H. P. DAVIS:—It seems to me there is no body of men better qualified to advise as to a suitable mining law than the annual meeting of the Canadian Mining Institute, and I suggest that a committee be appointed at this annual meeting to take up this matter.

COL. HAY:—An effort was made along this line in Toronto. My recollection is a committee was appointed and when they met it was decided they were starting at the wrong end. They decided there was no use to sit down at one point and try to frame a law without the time and funds and machinery requisite to such an important work. To my mind the only way to make a law is to have a commission appointed at which the Provincial Governments and all interested parties will be represented. In this way only, useful work can be done. There have been many abortive attempts to make amendments to the Ontario Mining Act emanating from Cobalt and Port Arthur and other points, but when the delegates would present their partly digested views to the Government they were all at sixes and sevens. It was a most unfortunate thing they were ever called upon separately to make suggestions, because the inevitable result was that it gave the Government an impression that the mining men did not know what they wanted. I have always strongly held the opinion that if this Institute recommended unanimously and forcibly to the Dominion and Provincial Governments that a commission should be appointed to cover the whole ground, it would be favourably received, and whatever the cost it would be a mere bagatelle compared with the enormous value to Canada of a Mining Act that would apply to the whole of the Dominion. There are plenty of men in Canada who are perfectly qualified to act on that commission and who could be induced to give up probably a year or more of their time and devote it to this important work.

MR. COSTE:—As a member of the Council, I will state that last year the Council discussed the advisability of urging the Government to complete the organization of the Mines Department by giving to that Department the control of the mining

lands at present administered by the Department of the Interior, and a committee was appointed to make certain recommendations on this score. I would now suggest that this committee be further empowered to represent to the Dominion Government that the annual meeting of the Canadian Mining Institute here assembled again recommends the appointment of a Royal Commission to secure information with a view to the framing of a suitable Mining Act.

THE PRESIDENT:—The committee will, I understand, report to the meeting on Friday.

THURSDAY AFTERNOON SESSION.

On re-assembling at 3 o'clock the proposed amendments to the by-laws as submitted by a committee nominated by the Council, and by Mr. J. B. Tyrrell and by Dr. A. E. Barlow, respectively, were discussed and in turn rejected. At the close of the discussion, at the suggestion of Dr. J. B. Porter, a resolution was moved by Col. A. M. Hay and seconded by Mr. J. Stevenson Brown, instructing the incoming Council to prepare a new set of by-laws for submission to the next annual meeting.

The motion was carried unanimously.

Mr. E. T. CORKILL, Inspector of Mines of Ontario, then read a paper on "MINE ACCIDENTS," which was productive of an interesting discussion.

THURSDAY EVENING.

A capital smoking concert, at which Mr. G. G. S. Lindsay, K.C., presided, was held during the evening in the "Ladies' Ordinary" of the hotel. Mr. W. T. Rodden, of Montreal, had been good enough to assume the responsibility of providing a suitable programme and his efforts in this regard were eminently successful. A feature of the evening's entertainment was an illustrated lecture delivered by Prof. J. F. Kemp, of Columbia University, on the "Origin of Ore Deposits," in connection with which a series of slides were displayed, and on the testimony of which trustworthy documents—for the camera, as is well known, is a most veracious instrument—it were mere obtuseness to dispute further the absolute soundness of Dr. Kemp's pet theory on ore deposition.

FRIDAY SESSIONS.

The Session opened at 10.30 a.m. with the presentation of a paper entitled "WHAT IS AN ORE," by Dr. J. F. KEMP, of Columbia University, New York. In introducing his subject Dr. Kemp said: For the past two or three years I have been engaged in assisting in the revision of the Century Dictionary; and in that work have been confronted with terms in mining geology, which required to be sharply and accurately defined. Under this classification we find the word "Ore." In talking with friends who have been called upon to give expert evidence in court, or who have had to interpret legal documents, it has been impressed upon me that the meaning which we may adopt for this word has often a somewhat important bearing. In my paper I have compiled, therefore, a number of definitions, nearly all of which have appeared in our more authoritative works, and have then discussed them in the hope that this may elicit some expression of opinion from members of the Institute as to "What is an ore."

Dr. KEMP then read his paper, which was followed by a lively discussion.

Other papers presented at the morning and afternoon sessions were: "OXYGEN BREATHING APPARATUS IN COAL MINES," by Mr. F. W. GRAY, of Sydney C.B., read by Mr. J. C. MURRAY, of Toronto, in the absence of the author; "PROBABLE CHEMICAL CHANGES IN THE FORMATION OF A COAL BED" by Mr. D.B. DOWLING of Ottawa; "THE ORIGIN AND HISTORY OF COAL AND PETROLEUM" by Mr. EUGENE COSTE, and "THE MINERAL RESOURCES OF THE SERPENTINE BELT, QUEBEC," by Prof. JOHN A. DRESSER, of Montreal.

THE NEW "MONEL" METAL.

Before the close of the session, Dr. J. BONSALL PORTER, of McGill University, asked permission to say a few words on the subject of the new alloy, known as "Monel" metal, now being developed by the Canadian Copper Company. Dr. Porter said: "Monel metal is a 'natural alloy' of copper and nickel. The Canadian Copper Company's Creighton mine produces an ore of copper and nickel in proportion of about one to three. In the beginning their metallurgical treatment was a rather complicated one de-

signed to produce pure nickel and pure copper from this mixed ore. They then discovered that the alloy made from their earlier operations was a rather promising material for engineering purposes. The matter has been more or less secretly developed, but it is now being made public. I am not going into the metallurgical discussion of the case at all, but it seems to me all engineers should know of this new and, in my opinion, very important material. Monel metal as produced by ordinary casting is said to have a little greater strength and a little more elasticity than good cast steel. By suitable heat treatment they produce from the castings a metal which has apparently all the good qualities of cast steel, and greater strength and better qualities than phospher bronze for instance, and still at a cost very much less than phospher bronze. Of course it is more costly than steel, but it has the remarkable and very valuable quality of not corroding.

"Even in its form of a cast metal it is said to have a tensile strength of 85,000 pounds and an elastic limit of something like 60,000 pounds. It is, therefore, an invaluable metal for the engineer to replace brasses and bronzes, which are now being used in large quantities because of their non-corrodability. If this Monel metal is more thoroughly refined and properly rolled, it is found that it can be cold drawn and considerably increased in elasticity. Its tensile strength can be brought up to about 100,000 pounds commercially. It rolls into sheets and bars and materials suitable for all sort of engineering purposes. I have here some specimens of wire, plate, and so forth. Here is a rolled bar which from the statement of the makers has a tensile strength of over 108,000 pounds. If the expectations of the makers of this material are fulfilled, it will be a most valuable addition to the engineering structural materials of the world. (Applause).

THE ANNUAL DINNER.

The Annual Dinner was held in the "Ladies' Ordinary" of the Windsor Hotel, at 8 o'clock, on Friday evening, covers being laid for one hundred and thirty. Among the official guests of the Institute on this occasion were His Excellency the Governor-General, Earl Grey; the Hon. Wm. Templeman, Minister of Mines of the Dominion; Mr. A. S. Goodeve, M.P., Rossland, B.C.; the

Hon. Frank Cochrane, Minister of Mines of Ontario; Dr. Peterson, Principal of McGill University, and Mr. George Mountain, President of the Canadian Society of Civil Engineers.

The toast of "The King" having been duly honoured, the President, Dr. W. G. Miller, in an appropriate speech, proposed the health of His Excellency the Governor-General, who on rising to respond was greeted with enthusiastic applause. His Excellency said:—

"Mr. Chairman and gentlemen:—I am glad to be able to disabuse your minds of the idea that either in my personal or in my official capacity I have neglected the important industry of mining in Canada. I am here as an old miner. (Cheers.) I have taken out my prospector's license many thousands of miles away, and I have gone through the same happy experiences which every man associated with mining must have gone through at some time in his experience. (Hear, hear!)

"I have been given to understand from the conversation at our table that I am talking to existing or future millionaires (laughter), and I feel how great the disadvantages of the Governor-General are, because I am perhaps the only person who is excluded from entering into that enviable fraternity. (Laughter.) It has been my happy experience wherever I have been in Canada to find myself in the society of what a friend of mine described as 'boosters,' not 'knockers.' Wherever I have been from the Atlantic to the Pacific, every man that I have met—every woman that I have met—believed that he or she was the owner of a little bit of land which was the king pin on which the whole of Canada or for that matter, the world, turned. (Laughter.) And so I hope it is the same with your interests in the mining district of Canada wherever they may be. I understand that whether you go to Cobalt, or to Elk lake, or to Gowganda, you will find no pessimists in any of those regions (Hear, hear!), and I am told by my friend, Mr. Farr, of Haileybury, that if I am not already a millionaire, it is my own fault in not accepting his invitation to go prospecting with him for a fortnight.

"Now, gentlemen, so much for my personal capacity.

"In my official capacity as Governor-General, I am very glad indeed to come here and be present at the annual dinner of the

Canadian Mining Institute. (Applause.) You are a comparatively young organization. I am told you were only born in 1898, and that you have now over 850 members. Well, gentlemen, the mining industry in itself is only a young industry in Canada. Until recently agriculture was the sole industry. The first prospectors and miners were necessarily agriculturists, with no knowledge of mining; consequently mining propositions, which under good management and transportation facilities would have been successful, turned out failures, owing to the want of skilled workers and intelligent direction. (Hear, hear!)

"It was that great Canadian, Prof. Grant, whose influence has left an impression on the life of Canada, who first recognized the need of a school of mining. He opened a school at Kingston in 1893, which has exerted a marked influence on technical education in this country. The mining departments of McGill and Toronto have also done much to supply trained men to intelligently develop this country's mineral resources. (Applause.)

"Only twenty years ago, I understand, the total value of your mineral output was ten million dollars. It almost trebled in the next ten years to twenty-eight million dollars, and in the last ten years it trebled again, and your total mineral output last year reached the great valuation of eighty-six millions of dollars. (Applause.)

"In 1908, owing to financial stringency and the lower prices of silver, lead and copper, the development of the mining industry was checked in its growth, but I do not think that any one who has seriously considered the position of mining in Canada can hesitate to believe that the next twenty years will see as great an increase in the value of the mineral output of Canada as that which has taken place in the last twenty years. (Cheers.)

"Now, gentlemen, I want to congratulate the Canadian Mining Institute upon the excellent work it is doing. I understand the object of the Institute is to place the mining industry of Canada upon an efficient and honest basis (applause); to meet both professional and educational requirements; to train the prospector as well as the mining engineer; to turn out technical men and provide them with opportunities for the interchange of views on

technical matters, and to make the full membership of the Institute a guarantee of both knowledge and character. (Applause.)

"I congratulate you upon the success of your excursion of last summer. I understand that the British and foreign representatives who took part in that tour were greatly impressed with the vast extent of the unprospected area of Canada, with the magnitude of your mining operations, and with the excellence of the mechanical appliances in operation, particularly in the Boundary district, which they had the pleasure of visiting, and I understand the visit was mutually advantageous in many respects. (Applause.)

"One result of this visit of British mining engineers of great benefit to Canada, will be that trustworthy information about Canadian mining propositions in London will now be obtainable, with the result that your mineral industry will be better safeguarded against artificial booms, which are invariably followed by unjustifiable slumps.

"Now, although I confess that my personal sympathies are more with agriculture than with mining, I willingly admit that there is no industry which contributes more to the general prosperity of a country than mining. (Cheers). Successful mining involves increased demands for the employment of capital and labour, industrial developments, commercial activity, land settlement, increased railway traffic and national prosperity. (Cheers).

"Although the mineral output of Canada at present is only $12.71 per capita of the population, and the value of the agricultural output is $63.90 per capita, yet, I think, it is quite possible that these proportions may some day be reversed. (Applause). You have, for example, the largest area of unprospected country upon the face of the globe. (Applause). Of the pre-Cambrian formation, covering an area of 2,000,000 square miles, and covering half of Canada, we only know, as yet, a little concerning the southern fringe. The wonderful results that have followed the incomplete prospecting of this territory justify the highest expectations for the future. (Applause). The coming mineral development means great prosperity for Canada. Although we have combed a little bit of the southern fringe of this great ore field, we have

combed out of this southern fringe the Cobalt silver mines, the nickel mines at Sudbury, the Lake Superior iron mines—the greatest iron mines in the world—and the Michigan copper mines, which occur in the same formation which has flowed over from the Laurentians into the United States. (Cheers).

"Now, gentlemen, I only wish to point out once more that the existence of a mining camp helps to bring about general prosperity. I understand that the per capita production of men engaged in mining is greater than that of men engaged in agriculture. (Applause). I have been making enquiries at Ottawa and am told that so far as Canada is concerned, the average per capita production of wealth in mining is twice and a half more than that of men engaged in agriculture; whereas according to the official reports issued by the Government of New South Wales, the men engaged in silver lead mining produce ten times more wealth, and gives ten times more employment to affiliated industries than the same number of men employed in agriculture. (Cheers). If that is a fact, and I do not believe it has been disputed, the conclusion is, that the more your mineral industry is developed, the greater will be the prosperity of the Dominion. (Applause).

"The development of mining means more consumption of timber, coal, coke and limestone; more freights, more machinery, more miners' supplies—all involving an increase of business and of railway traffics, and a consequent advance in land values. The systematic and organized development of the mining industry in Canada is, therefore, of national importance. (Applause).

"I have pointed out the importance of the mining industry to your railways. It was a great surprise to me to discover that in Canada, which we are apt to regard as a country mainly agricultural, the business of the mines afforded 33 per cent. of the total railway traffics during the year 1907, while the products of agriculture afforded only 17 per cent.; and in the United States the difference in favour of mines is still greater—the mines affording 54 per cent. of the total business done by the railways, and agriculture only 9 per cent. The importance of developing the mining industry will thus be obvious to every on. At present the cars which take the wheat from the Northwest to the seaports are hauled back empty across half a continent. The development of the mining industry will enable these railway companies to haul

back full cars instead of empties. (Applause). With the development of your mining industry, your railway companies may look forward to full trains both ways, and will consequently be in a position to offer lower rates to the farmers.

"Mineral developments, while supplying the farmers of Canada with good markets for the produce of their farms, will also provide a balancing compensation to the increasing weight of the western half of Canada. Therefore, I say, develop your unprospected areas, multiply your silver and your nickel mines, and you will find that the populations created by successful mining industry will help to balance the west, however quickly it may increase, and will thus help to establish the stability of a national equilibrium." (Cheers).

Dr. Adams, who acted as toast master throughout the evening, proposed the toast, "The Dominion Government," which was responded to by the Honorable Mr. Templeman, Minister of Mines, and Mr. Goodeve, M.P., of British Columbia.

THE HONORABLE MR. TEMPLEMAN, upon rising to respond to the toast, was received with cheers. He said: "Your Excellency, Mr. President, and members of the Canadian Mining Institute, permit me to thank you very sincerely on behalf of the Government of Canada for the cordial manner in which this toast has been received by this distinguished gathering. I take it, Mr. Chairman, that Canadians fully appreciate the inestimable privileges which we enjoy under our system of responsible government. (Hear, hear!).

"I do not think in all the wide world there is a more democratic government than the Government of Canada. (Applause).

"Mr. President, I feel highly honoured, and I recognize fully the great privilege and the great responsibilities which devolve upon me as the first Minister of Mines in the Dominion of Canada. The Department of Mines was created only two years ago, and very largely upon the representations of the Canadian Mining Institute. (Applause). Coming, as I do, from the chief mining province of Canada—British Columbia (Hear, hear!), we felt out there that such a department was necessary and that it was in the interest of Canada that a department of the Government should have charge of the great mining industry, pretty much in

the same way as the Department of Agriculture has charge of the great agricultural interests of this country, and we believed that after a time, possibly it would do as much for the mining interest of Canada as the Department of Agriculture has done for the great agricultural interests, and that we all know is a very great deal indeed. (Applause).

"The development of the mining industry in Canada has been a matter of very slow growth, just as in all probability the growth and development of the Department of Mines may be somewhat slower than we all may wish, because it is impossible to travel more rapidly than we are doing, for very many reasons. As His Excellency remarked, up to almost the present time, Canada has been recognized as an agricultural country. The miners in British Columbia were the pioneers of that great province, and of course agriculture followed mining there; but in this province, and in the other provinces of the East, mining is following agriculture. We have been mining, however, in British Columbia for thirty or forty years past; we have had a very large and very intelligent mining population. I would imagine that probably the majority of the people of British Columbia, until very recent years at all events, have been directly or indirectly engaged in mining. In the East I am glad to note that the mining population is increasing rapidly, and that mining men, prospectors and mining engineers are becoming very much more numerous than they were a few years ago. (Hear, hear!). There is no question about it, but that the mining interests of Canada are developing rapidly. The Department of Mines was created for the purpose of encouraging this great industry, and you, gentlemen, even more so than myself, know that here in Canada we have probably one of the greatest mining countries in the world. (Cheers).

"It has been stated that within a decade or so, the mining development of Canada has increased from some twenty or thirty millions of dollars annually to between eighty and ninety millions annually. Why, sir, it seems to me, judging from the development of the last five or ten years, having regard to the development that has taken place with respect to transportation facilities in the west, in the northern portion of Ontario and in the northern portion of Quebec, that the development that will take place in

the next decade will enormously surpass anything that has taken place in the immediate past, and that within another ten or twenty years, instead of an annual output of eighty or ninety million, we will record it in tens of hundreds of million. (Cheers).

"The Department of Mines of the Dominion is only in its infancy, just as the mining industry is in its infancy. We had the nucleus of such a department in the old Geological Survey at Ottawa. We have been trying within the last year or two to strengthen this department. We have not done as much as we would have liked in that time, but we intend to do more and more every year. (Hear, hear!). We realize that there is a great work before the Department of Mines. Just as the Department of Agriculture has supervision over, and exerts a great educational influence in all the provinces, in respect of agriculture, so as concerning mining, the Department of Mines at Ottawa will have the same duties to perform in assisting and encouraging this great industry. (Applause).

"Since its creation, the Department of Mines has not been altogether inactive. We have carried on very large and very important investigations in the matter of the electrical smelting of iron ores, and I believe we are at present within measurable distance of the successful application of electrical smelting to iron ores in the provinces of Quebec and Ontario.

"We, who come from British Columbia where there are inexhaustible fields of coal, and those of you who come from Nova Scotia where there are equally inexhaustible fields of coal, are not probably so much concerned in the utilization of water powers, or in the development of the peat bogs as are here in this province, but, sir, there are no questions that should more impress the people of Ontario and Quebec than the successful utilization of the great natural resources, the water powers for the development of electrical power and the development of your peat bogs. We are carrying on to-day—although I am criticized in some places for doing so—and will have completed within a reasonably short time an investigation into the possibilities of the utilization of the enormous peat bogs which you have in these two provinces of Ontario and Quebec, and if we can turn your peat now useless and worthless, into electrical energy, you will add millions and millions to the wealth of these provinces. (Applause).

"We are carrying on numerous other experiments of a technical and economic character in the Department of Mines which I need not refer to further. I have said that I believe that Canada will become one of the greatest, if not the greatest, mining country in the world. (Hear, hear!). We have every reason to think so. At the present moment, in some respects, Canada has a monoply of some of the most valuable economic minerals in the world. (Applause). I have been informed that Canada produces some 85 to 90 per cent. of the total output of the asbestos of the world. (Applause). I believe it is a fact that Canada produces to-day over 50 per cent. of the nickel output of the world. (Applause). We have the largest nickel deposits in the world within one hundred miles of the City of Ottawa. There is no country in the world to-day that has as valuable mica deposits as Canada, and mica of course has become one of the great economic minerals due to the development of electricity.

"We have up in Cobalt the richest silver mining camp in the world. (Cheers). Now, these are claims that are susceptible of proof, and hence I have justification for my belief that within a measurably short time, Canada will become the greatest mining country in the world.

"Now, Mr. Chairman, I desire to compliment the Canadian Mining Institute upon the remarkable success of the excursion which you, in company with our scientific friends from the United Kingdom and Germany, made to the West last year. I met the Excursion party at Victoria, and I know that your guests fully enjoyed themselves and that they had an opportunity of seeing at the best the great mining industries of the West. I don't know that we have done anything in recent years, along excursion lines at all events, that will enure more to the benefit of the country than that same excursion, and let me assure you if it is in my power in the future to help the Canadian Mining Institute, I shall be very happy to do so." (Applause.)

MR. GOODEVE, M.P. of Rossland, B.C. followed the Honorable Mr. Templeman in responding to the toast "The Dominion Government," and expressed much pleasure at being present. He referred with enthusiasm to the great natural resources of the different provinces, and complimented the members of the

Canadian Mining Institute upon their energy and progressiveness in the development of the mineral resources of the Dominion.

The toast of "The Provincial Governments" was proposed by Mr. Lindsay, General Manager of the Crow's Nest Coal Company, and responded to by the Honorable Frank Cochrane, Minister of Mines of Ontario, and Mr. Obalski, Superintendent of Mines of Quebec, representing the Honorable Mr. Devlin, who was unavoidably prevented from attending.

MR. LINDSAY said: "I feel that this toast will be drunk with enthusiasm, because I am sure that every member of the Canadian Mining Institute recognizes and appreciates what the Provincial Governments have done in the matter of the appointment of the officials who have been selected and placed in charge of the work of developing the great mineral resources of the country. (Applause). When we think of our friend, Mr. Obalski, of Quebec, Dr. Miller, of Ontario, and Mr. Robertson and his colleagues in British Columbia, we can realize that the example that has been set by the Federal administration in selecting extremely able men to guide the destinies of these great matters has been notably followed by the provinces in the selection of these estimable gentlemen. (Hear, hear!)."

The toast of the "Mining Industry" was proposed by Mr. George R. Smith, and responded to by Mr. R. W. Brock, Mr. John E. Hardman and Mr. F. W. Guernsey.

MR. SMITH said:—"We have heard statements to-night of the wonderful mineral resources of this country. It has been stated that Canada produced over ten millions of dollars in value of silver and about ten million dollars in value of gold in the year 1908, and we are also told that this production is likely to double or even treble in the next year or two. Now, as a practical mining man, and as representing one of the mining industries in Canada, while not mining gold or silver, I cannot help but feel that if this immense quantity of gold and silver is mined in this country, that the time is ripe for us and, particularly for you gentlemen who are interested in those two industries, to consider the coinage of those two metals. (Hear, hear!).

"It seems to me, gentlemen, there is altogether too great a circulation in Canada of silver coins of another country. Producing the vast amount of silver that we do produce, it seems to

me that the Government should see to it, that no other coinage shall be admitted from any other country and put in circulation in Canada except coinage minted from our own silver, and the same remark applies also to the gold coinage. (Hear, hear!).

"Now, gentlemen, in Canada the mining industry is one that is not confined to any province or any part of any province. It has been aptly stated to-night that it is an industry that reaches from the Atlantic to the Pacific—from Cape Breton to British Columbia. It has been stated that British Columbia produces more than Nova Scotia or Ontario, and the gentlemen have stated that Ontario produces more than all the other provinces; yet we in the Province of Quebec know that we are producing the only thing in the mineral industry that is of absolute value in the hereafter to all of you." (Laughter).

MR. JOHN E. HARDMAN, in replying to the toast, remarked that:—"Mr. Templeman in his speech was very laudatory to this Institute, and we acknowledge the compliment he paid us, and we think we have earned it. At the same time he was willing to say something in regard to the lack of laws respecting the governing of the Dominion mineral lands. I hope that Mr. Templeman will excuse me if I say so far as the mining industry is concerned, that the best that could be done to promote its welfare would be the passage of a good sound solid law from which there could be no deviation unknown to the miner—a law that would be in a reasonable degree permanent and not subject to orders in council which are not fully published in advance. The basis of the mining industry is a reasonable certainty of title. (Hear, hear!).

"I wish also to reiterate what Mr. Brock has just stated and that is that the first requisite in the successful development of our mineral resources is that they should be developed, not only by men of brain and brawn, but by men of a strong moral fibre—men who will put their heels down on 'wildcatting' and do their very best to place the mining industry in as honourable a position as any other industry in this wide world. (Applause).

MR. E. L. FRALECK proposed the toast of "Sister Societies," and DR. WOODMAN in responding, said that as a member of the American Institute he wished to congratulate the Canadian Institute upon its work in the past, and upon the present eminently

satisfactory position the society occupied. He added:—"The political boundaries between Canada and the United States are artificial enough in all conscience, but as to the boundaries between the scientific men of the two countries, there are none. (Applause). The winning of ore is a fraternity all the world over, and whether we be white, black, yellow or brown, we are engaged in the same business, and I know that the American Institute feels proud to be on friendly terms with the Canadian Mining Institute. (Applause).

DR. A. C. LANE, representing the Lake Superior Institute and MR. MOUNTAIN, the Canadian Society of Civil Engineers, also responded.

The Toast-Master, Dr. Adams, in proposing the toast "Our Guests," said:—At the meeting of the American Geological Society held at Ottawa some years ago, we had a very interesting discourse from Prof. Kemp, of Columbia University, on the subject of "The Geology of Jell." It was a sort of moral address preached from the text "Jam the jam thing to Jell." Since that time I understand Dr. Kemp has continued to study these deep subjects, and I think his opinion on the origin of ore deposits, which are always associated with igneous rock and sulphur fumes, and so forth, has been largely influenced by his studies. I ask you to drink to the health of "Our Guests," and I couple with it the name of Dr. Kemp of Columbia University. (Applause).

DR. KEMP responded as follows:—"I am very much tempted to go on and discuss in still greater detail the Geology of Jell, because there is no place, as Mr. Lindsay and Mr. Smith have already intimated, more appropriate in which to take up the discussion of this subject than the province which produces 90 per cent. of the asbestos of the world. (Applause).

"I endeavoured to show my Canadian friends at a previous gathering that Jell was not such a bad place after all. (Laughter). One of my fellow citizens in New York died a short time ago and went down to Jell. After he had passed Erebus, one of the little Jevils met him and said: 'Would you not like something to drink?' He said: 'Thank you, I will take a high-ball,' and the little Jevil then said, 'Will you have some ice in it?' The New Yorker, somewhat surprised, said, 'Do you really have ice here?' The little Jevil replied: 'Oh, yes, in the last few years

all the distinguished scientific men have come down here and now we have all the modern improvements.' (Laughter).

"However, my own studies for the last two or three years have been directed towards the geology of another district. We had a little dinner sometime ago in New York, during which an interesting discussion took place on 'The Geologie du Ciel,' and one of the gentlemen present referred to the case of an energetic prospector from the Klondike, who had somehow or other got up past St. Peter, and before the authorities were aware of it, he had the Golden Street dug up from one end to the other. It didn't seem to trouble him at all whether the native metal was ore or not. He had it nearly all packed off before they could stop him. (Laughter).

"Some years ago I had a good friend who was a missionary out in Nevada in the early days of the mining excitement. He was an Episcopal clergyman, and the only opportunity he had to hold services was to get the people who ran the bar of the camp to turn it over to him for two hours on Sunday afternoon. He would then spread his altar cloth on the bar and hold service, and after he had finished the service, the bar resumed business. He was going down to San Francisco on the Central Pacific Railway one day with some of his mining friends, and they said, 'See here, you've been out here now for two years and you haven't made any more than your salary, which is small at that. Up in that cañon that we are just passing we have a mining property and we are going down to San Francisco to put the shares on the market. We are going to give you a thousand of those shares, and when the value goes to ten dollars you must sell it quick.' The missionary said, 'Have you sunk a shaft? How does the ore run? What does it assay?' His mining friends said, 'No, we haven't got any ore. The worse thing you can have in a mine is ore.' (Laughter.)

"This was a definition that probably did not occur to any one during our discussions this morning, but I presume that mine is what in Canada you would call a 'wildcat,' and the report upon it might be described in the words of Elbert Hubbard in defining a miracle. 'A miracle,' he said, 'is a physical event described by one to whom it was related by men who did not see it.' (Laughter).

"Mr. Chairman, on behalf of the guests of the Institute, I wish to offer you our most sincere thanks for the boundless hospitality with which we have been greeted. We mining men have rather grown to expect it when we are with gatherings of our fellows. Miners, as a rule, are whole-souled generous men. A miner adds a distinct increment to the general wealth of the nation wherever he works. (Hear, hear!). What he wins from the ground is something new and something not previously possessed by anyone. He takes it from no man and he adds it to the wealth of the community. (Hear, hear!).

"Some years ago Mr. D. Wallace James, one of our most public spirited citizens, defined the miner's calling as the most legitimate of all, because while the agriculturist harvested what he himself had sown, the miner gathered what Divine Providence had itself sown in the ground.

"At the dinner three years ago, to which Dr. Adams has referred, we were discussing the origin of diamonds in particular, and it was brought up before the Geological Society that there had been a number of finds of diamonds in Michigan and Wisconsin, which had doubtless emigrated across the border during the last glacial epoch, aided in transit by the Continental Ice Sheet. In speaking at the dinner that evening, His Excellency Earl Grey will perhaps recall that he established two periods of emigration in connection with Canada; the first was when the Continental Ice Sheet moved the diamonds and boulders and much of the fertile real estate down across the border and left it for the Americans to cultivate; and the second in modern times, when emigration has set in the other way, with the opening of the great wheat fields of Alberta and Western Canada, the American farmers are coming across the border and are 'evening up things,' and they are coming in in such numbers as to cause serious apprehension to us on the other side. We have been more or less discouraged until my present visit to Montreal; but I have taken a bit of heart from the condition of affairs here, because anybody who looks out of the windows can see that we are just entering on a new glacial epoch, and the first thing we shall know is that probably in a year or two, from the present outlook, there will be another great Continental Ice Sheet spreading over Canada and

driving all the farmers up in Alberta across the border again to settle somewhere between Virginia and Florida. (Laughter).

"In return for the cordial welcome you have given us, I can only say that when you come across the border, we will also welcome you, and although you travel upon a vehicle as cold as a continental glacier, we will endeavour to give you a welcome as warm as Jell." (Laughter and applause).

"The Press" was proposed in happy terms by Major Leckie, and responded to by Mr. Knight, Mr. Neil McDonald and Mr. Farr.

The proceedings then terminated after the singing of the National Anthem and "Auld Lang Syne."

WESTERN BRANCH MEETINGS.

At Victoria, British Columbia, Sept. 22nd, 1908.

(Reported by E. Jacobs, Secretary.)

The Western Branch of the Canadian Mining Institute held its third general meeting at Victoria, British Columbia, on Tuesday, September 22, 1908. This meeting was of unusual importance for the reason that it was held concurrently with the visit to Victoria of the Canadian Mining Institute Summer Excursion, in which party were 21 gentlemen from Europe, of whom six were official guests of the Institute, and the remainder unofficial guests. In addition there were 17 members of the Institute, other than the 23 members present who are also members of the Western Branch. Of the visiting members, one was from Nova Scotia, five from Quebec, and eleven from Ontario. Then one of the Patrons of the Institute—the Hon. W. Templeman, M.P., of Victoria, B.C., Minister of Mines for the Dominion—was also present. The total attendance of guests and members of the Institute was therefore 62; numerous prominent citizens of Victoria also attended the business meeting, among them: Hon. Richard McBride, Premier and Minister of Mines of British Columbia; Hon. Dr. Young, Provincial Secretary and Minister of Education; and Mr. Herbert Carmichael, Provincial Assayer, who in the unavoidable absence of Mr. W. Fleet Robertson, Provincial Mineralogist, officially represented the Bureau of Mines of British Columbia.

It is noteworthy that the Department of Mines of Canada was represented at the meeting by the following officials: the Hon. W. Templeman, M.P., Minister of Mines; Mr. T. W. Brock, acting director of the Geological Survey; Messrs. Chas. Camsell and O. E. LeRoy, geologists; and Mr. John McLeish, statistician. Mr. Jas. White, Dominion Geographer, of the Department of the Interior, was also in attendance.

The Canadian Mining Institute was represented by the following: Dr. Willet G. Miller, president; Mr. H. Mortimer-Lamb, secretary; Mr. J. Stevenson Brown, treasurer; Messrs. R. W. Brock, Eugene Coste, and Chas Fergie, and Prof. J. C. Gwillim, members of the Council. Other visiting members were: Dr. B. E. Fernow, Toronto; Mr. E. L. Fraleck, Cobalt; Mr. W. Stanley Lecky, Montreal; Mr. G. G. S. Lindsey, Toronto, president of the Crow's Nest Pass Coal Company; Mr. J. Obalski, Que; and Mr. Gordon McT. Pyke, Montreal.

The visitors from Europe were: Official: Mr. John Ashworth, president of the Manchester Geological and Mining Society, Manchester, England; Mr. James Barrowman, secretary of the Mining Institute of Scotland, Hamilton, Scotland; Mr. Wm. Frecheville, past president of the Institution of Mining and Metallurgy, London, England; Mr. Walter Johnson, of the Iron and Steel Institute, Middlesborough, England; Mr. Hugh F. Marriott, member of the council of the Institution of Mining and Metallurgy, London, England; and Dr. H. Potonié, chief geologist of the Prussian Geological Survey, Berlin, Germany. Unofficial: Mr. Roger Beck, Swansea, Wales; Mr. Clifford E. Bloomer, Birmingham, England; Mr. R. E. Commans, London, England; Mr. John Gerrard, H. M. Inspector of Mines, Worsley, Manchester, England; Herr Bergrat Goebel, Arnsberg, Germany; Mr. John Hogg, Cambuslang, Scotland; Messrs. Mark Hurll and Mark Hurll, Jr., Glasgow, Scotland; Herr Ernst Kraynik, Berlin, Germany; Mr. D. B. Langford, London, England; Mr. Samuel Mavor, Glasgow, Scotland; Mr. W. J. Rees, Swansea, Wales; Mr. Sydney W. Smith, London, England; Mr. R. W. Tallis, South Wales; Mr. Andrew Watson, Glasgow, Scotland. Nearly all these gentlemen are members respectively, of one or other of the old established and influential geological, mining, or metallurgical institutions of Great Britain or Continental Europe.

The members of the Western Branch present were: Mr. A. B. W. Hodges, of Grand Forks, Boundary district, chairman; Mr. E. Jacobs, of Victoria, secretary; Messrs. Andrew Colville and F. H. Shepherd, of Nanaimo; K. C. Allen, H. P. Dickinson and A. G. Larson, of Rossland; Alex. Grant, of Van Anda, Texada Island; W. H. Armstrong, J. West Collis, A. G. Langley, Chas. F. Law,

T. J. Smith, and Geo. Sheldon-Williams, of Vancouver; J. W. Astley, Wm. Blakemore, Lewis Hind, W. D. McGregor, W. J. Sutton, W. H. Trewartha-James and Mrs. R. W. Young, of Victoria; Mr. Thos. Kiddie, of Northport, Washington, and Mr. J. Cleveland Haas, of Spokane, Washington.

The business session was held in the ministers' room, Parliament Buildings, which had been courteously placed at the disposal of the Institute by the Provincial Government. Mr. A. B. W. Hodges, Chairman of the branch, presided, and after he had called the meeting to order, the Hon. Richard McBride, Premier of British Columbia, on behalf of the Government, extended a very hearty welcome to the visitors.

The Hon. Wm. Templeman, Minister of Mines for Canada, also welcomed the visitors.

Dr. Miller, president, replied on behalf of the Institute, and Mr. Wm. Frecheville on behalf of the guests of the Institute.

Mr. W. J. Sutton, gave an address on the Geology and Mineralogy of Vancouver Island, B.C., and exhibited a large map to indicate the situation of the various localities of which he made mention.

Mr. Hodges read a paper he had prepared on "The Importance of Low-grade Boundary Ores in the Copper Production of Canada," and a brief discussion followed.

Mr. Herbert Carmichael gave the meeting some information relative to mining and smelting on the coast of British Columbia.

Mr. John Ashworth, who is a corresponding member of the Institute, read a paper, prepared by his brother, Mr. James Ashworth, and himself, on the Coal Dust problem. There was no time for discussion of this important paper.

An account of the Construction and Method of Operating Ore Bunkers at Skagway, Alaska, kindly contributed by Mr. A. L. Berdoe, general manager of the White Pass and Yukon Route, at the request of the secretary, was read by title, and was held for publication later.

Mr. Sutton invited any of those present particularly interested in geology and mineralogy to inspect his large and varied collection of rock and mineral specimens at his residence in Victoria.

A comprehensive vote of thanks, moved by Mr. Trewartha-James, and seconded by Mr. Coste, to all who had assisted in the entertainment of the visitors and in making the meeting a success and the stay in Victoria so enjoyable was passed, and the proceedings were brought to a close.

AT GREENWOOD, B.C. JAN. 25TH, 1909.

(Reported by E. JACOBS, Secretary)

The fourth general meeting of members of the Western Branch of the Canadian Mining Institute was opened in the Court House, Greenwood, B.C., on Monday afternoon, January 25th.

In the temporary absence from the province of the Chairman of the branch, Mr. A. B. W. Hodges, of Grand Forks, general superintendent of the Granby Consolidated Mining, Smelting and Power Company, Ltd., Mr. S. S. Fowler, of Riondel, general manager of the Canadian Metal Company, Ltd., was voted to the chair.

The following members were present: from Nelson: B. A. Isaac, Louis Pratt and J. A. Whittier. Riondel, Kootenay Lake: S. S. Fowler. Kaslo: J. L. Retallack. Rossland: H. P. Dickinson and A. G. Larson. Northport, Wash.: Thos. Kiddie. Victoria: E. Jacobs (secretary of branch). Phœnix: Chas. Rundberg and O. B. Smith. Greenwood: C. S. Baker, S. E. Belt, F. Keffer, M. D. McIntosh and W. C. H. Wilson. Messrs. A. Burnett, Greenwood: R. W. Hinton, Jas. McGregor and Nelson; and Horace G. Nichols, Ymir, were also present.

The mayor, Mr. Bunting, cordially welcomed to Greenwood the visiting members of the Institute and invited their attention to the important mineral resources and mining and smelting industries of the Boundary district. In it there are numerous properties on which the occurrence of ores, high in silver and gold, had been proved, in addition to the large copper mines, the abundant production of w ich was well and widely known. Much capital was needed, though, for the more extensive development of the mineral resources of the district, and he hoped that the meeting of the Institute at Greenwood would have the effect of directing the attention of capitalists to the favourable field the Boundary offers for the investment of money in mining enterprises. He was pleased to have been afforded this opportunity of welcoming

the visitors to Greenwood and the district, and hoped their visit would prove both pleasant and profitable to them.

Mr. Dixon, one of the city aldermen, also expressed his gratification at being present on this occasion, and had pleasure in adding his welcome to that extended by the mayor.

The Chairman brought forward the matter of the necessity that exists for assisting the electro-thermic zinc smelting industry recently started at Nelson after years of outlay of time and money in conducting experiments in this connection. It had been proved that spelter could be made by a process more effectively developed at Nelson, but those who had thus far financed the enterprise were in need of assistance to carry it to a successful issue. The provincial government had assisted to the extent of $20,000; he now submitted for discussion and consideration of the meeting the question of whether or not it is desirable to ask the Dominion Government to assist this industry in the direction indicated.

Messrs. Kiddie, Retallack, Nichols, Jacobs, Dickinson, and Pratt took part in the discussion which ensued. Finding the expression of opinion unanimously favourable, the Chairman appointed Messrs. Kiddie, Pratt and Dickinson a committee to draft a resolution embodying the views expressed and to present same to the meeting next morning. At the suggestion of Mr. Kiddie, supported by Mr. Retallack, the same committee was assigned the duty of preparing a resolution expressive of appreciation of the action of the provincial government in giving financial aid to the enterprise under consideration.

After attention had been called to the suggestion made at meeting of the branch held last May in Rossland that an application should be made to the provincial government to make a money grant for the use of the local branch of the Institute, similar to that made to Farmer's Institutes and other provincial organizations, the meeting adjourned to Tuesday morning at nine o'clock.

Tuesday Morning's Meeting.

On resuming on Tuesday morning, with Mr. Fowler in the chair, the report of the scrutineers was received. The Chairman then announced the result of the ballot, as follows:—For Chairman of the Branch, Mr. Thomas Kiddie, manager of the Le Roi Mining

company's smelting works at Northport. For members of branch council:—Messrs. W. H. Armstrong, managing director of the Nicola Valley Coal and Coke company, Vancouver; N. McL. Curran, manager of the North Star Mining company, Kimberley, East Kootenay; S. S. Fowler, general manager of the Canadian Metal Company, Riondel, Ainsworth mining division; A. H. Gracey, Nelson; J. Cleveland Haas, Spokane, Washington, U.S.A.; John Hopp, Barkerville, Cariboo; J. D. Hurd, general manager of the Crow's Nest Pass Coal and Coke Company, Fernie, East Kootenay; James McEvoy, manager of the German Development Company, Kananaskis, Alberta; F. C. Merry, superintendent of the Ferguson Mines, Ltd., Ferguson, Lardeau; P. L. Naismith, manager of the Alberta Railway and Coal Company, Lethbridge, Alberta; Lewis Stockett, manager of the Hosmer Mines, Ltd.. Hosmer, Crow's Nest Pass; and Thos. R. Stockett, manager of the Western Fuel Company, Nanaimo, Vancouver Island. The *ex-officio* members of the council are the following:—Messrs. W. M. Brewer, Tyee Copper Company, Victoria, Vancouver Island; A. B. W. Hodges, general superintendent of the Granby Consolidated Mining, Smelting and Power Company, Grand Forks; Frederic Keffer, engineer and geologist for the British Columbia Copper Company, Greenwood; A. J. McNab, metallurgist for the Consolidated Mining and Smelting Company of Canada, Trail; Wm. Fleet Robertson, provincial mineralogist, Victoria; O. B. Smith, mine superintendent for the Granby Con. Mining, Smelting and P. Company; and R. H. Stewart, superintendent of mines for the Consolidated M. and S. Company, Rossland.

Mr. Fowler called upon Mr. Kiddie to at once assume his new duties as Chairman of the branch, which office he had great pleasure in seeing the new Chairman elected to. Mr. Kiddie had for years been actively interested in the mining and metallurgical industries of British Columbia and, too, he had been a zealous worker in the interests of the Canadian Mining Institute, on the council of which he had served for a term. As a member of the branch, too, he had done much to make the branch meetings successful, and to interest others in them. He heartily congratulated him upon his practically unanimous election as chairman, and would now vacate the chair in his favour.

Mr. Kiddie, who was received with applause, briefly returned thanks for the honour done him in electing him chairman and assured the meeting that he would continue his endeavours for the advancement of the Institute and the success of the branch in particular. He reminded them that the large measure of success the branch had already enjoyed was attributed mainly to the activity of the chairman for the year just closed—Mr. A. B. W. Hodges—and he suggested that a hearty vote of thanks for his services should be passed by the meeting and communicated to Mr. Hodges by the Secretary.

It was unanimously resolved, on the motion of Mr. Fowler, seconded by Mr. Keffer, "That this meeting of the Western Branch of the Canadian Mining Institute hereby expresses its appreciation of the services rendered by the retiring chairman, Mr. A. B. W. Hodges, not only in the organization of this branch but throughout the past year."

On motion of Mr. Pratt, seconded by Mr. Larson, the secretary was instructed to send to Prof. R. W. Brock, director of the Geological Survey, the following telegram:—"We heartily congratulate you on your appointment as Director of the Geological Survey and express our appreciation that your valuable work in the past has thus been acknowledged."

On motion of Mr. Kiddie, seconded by Mr. Retallack, it was resolved: "That this the Western Branch of the Canadian Mining Institute, in meeting assembled, does hereby express its approval and appreciation of the action of the Federal Government, through its Department of Mines, in seeking a solution of the difficulties attendant on the economical smelting of eastern iron ores, by practical experiments in electro-thermic reduction, conducted at the public cost.

"In this connection this meeting commends to the Government the desirability of aiding in and contributing to the advanced experiments which have already been made in British Columbia towards the separation and reduction of lead-zinc ores by electro-thermic energy. These experiments have demonstrated the practicability of the separation of metallic zinc from metallic lead, and its recovery as spelter from complex lead-zinc ores. Important deposits of such ores occur in this Province and remain unworked through lack of economic reduction facilities. In the

opinion of this meeting, a solution of this problem, will be of very great importance to the mining industry of the Dominion."

On the motion of Mr. Fowler, seconded by Mr. Keffer, it was resolved: "That this meeting of the Western Branch of the Canadian Mining Institute hereby endorses and expresses its appreciation of the action of the Provincial Government and especially that of the Honourable the Premier and Minister of Mines, in aiding the important experiments which are being conducted at Nelson towards the separation and reduction of complex lead zinc ores by electro-thermic means."

On motion of Mr. Keffer, seconded by Mr. Belt, it was resolved "That the council of the Western Branch request at the next general meeting of the Institute in Montreal that, in view of the isolation of the western members from the main body of the Institute, the appropriation available for the purpose of defraying the ordinary expenses of this branch be increased from twenty-five to forty per cent. (25 to 40%) of the fees of members in good standing enrolled as members of the branch, and that the money so payable be remitted to the credit of the western branch in quarterly instalments, for disbursement under the direction of the council of the branch."

In this connection the Secretary mentioned that at the time the branch was organized, in January, 1908, there was a western membership of the Institute of about 133 members, including 53 elected in October, 1907, following the visit to the West of the Secretary of the Institute, Mr. H. Mortimer-Lamb. During 1908, 61 members had been elected, which, after deducting five who had either resigned or gone East, left a western membership of 189. Six applications for membership are now awaiting action by the council, and upon election of applicants the membership of the western branch will number 195.

Resolved, on motion of Mr. W. C. H. Wilson, seconded by Mr. Fowler: "That this meeting hereby expresses its appreciation of the services rendered to the mining industry by the first and present Minister of Mines, the Hon. Wm. Templeman, and of the action of the Right Hon. the Premier of Canada in retaining the Hon. Mr. Templeman in that office."

A resolution was also adopted, on the motion of Mr. Keffer, seconded by Mr. Fowler, expressing appreciation of the services

rendered the mining industry of British Columbia by the "Mining Record," published at Victoria and during the last four years edited by the present secretary of the Western Branch of the Institute, and trusting that circumstances will soon permit Mr. Jacobs to again direct its publication. Messrs. Keffer, Fowler, Kiddie and Retallack all spoke to this motion, mentioning especially the general reliability and independent character of the "Mining Record."

Mr. A. Burnett, of the B. C. Copper Company's engineering staff, read a paper entitled "Some Notes on Gas Power and its Applicability to Mining." This was discussed at length by Mr. R. W. Hinton, while Mr. Fowler complimented the writer upon the manner in which he had dealt with his subject, and upon the clearness and appropriateness of the language he had used in his paper. Mr. Burnett replied to a question asked by Mr. Kiddie as to the relative cost of gas power and electricity, respectively.

Mr. M. D. McIntosh, superintendent of the Mother Lode mine, read a paper on "Mining Methods and Equipment at the Mother Lode Mine, Boundary District," and at its close explained, at Mr. Fowler's request, the advantage gained in using a spiral raise as distinguished from a straight raise.

Mr. Kiddie gave the meeting some information concerning experiments he had been making in riffle sampling, which appeared to give more generally reliable results than cone sampling. As there was not time to go fully into this subject then he would defer making more extended reference to it until another meeting. Meanwhile he would have tried riffle sampling on a larger scale and would so be in a position later to prepare a paper giving conclusions based upon greater practical experience of this method than he had yet had. Mr. Keffer added a few remarks relative to the results obtained when sampling ores from the Mother Lode mine.

COBALT BRANCH MEETINGS

AT COBALT, APRIL 21ST, 1909.

(Reported by A. COLE, Secretary.)

At a meeting of the Cobalt Branch held in the Prospect Hotel on the 21st April, 1909, the following officers were elected:

Mr. R. W. Brigstocke, Chairman; Mr. Arthur A. Cole, Secretary; Mr. E. L. Fraleck, Mr. Milton T. Culbert, Mr. R. A. Bryce, Mr. S. H. Logan, Mr. T. Jones, Committee.

JUNE 23RD, 1909.

A meeting of the Cobalt Branch of the Canadian Mining Institute was held in the Town Hall of Cobalt, on Wednesday, June 23rd, at 8 p.m. There were present sixty members and guests. A paper was read by Mr. G. R. Mickle, entitled "The Probable Number of Productive Veins in the Cobalt District."

A room has been set aside by the Town Council, in the Town Hall, for the use of the Cobalt Branch of the Institute, as a reading room and library. This has been fitted up with shelves and book cases to take care of the books and specimens which are already beginning to accumulate.

McGILL MINING SOCIETY MEETINGS.

At Montreal, Jan. 22nd, 1909.

(Reported by E. Penny, Secretary.)

A meeting of the McGill Mining Society in conjunction with the Montreal Branch of the Institute was held in the lecture theatre of the Chemistry building, McGill University, on Friday evening, January 22nd, at 8.30 o'clock. The speaker of the evening was Mr. D. B. Dowling, a member of the staff of the Geological Survey of Canada, who delivered a most interesting address on the subject of "The Western Coal Fields of Canada."

The chairman, Dr. J. Bonsall Porter, in introducing Mr. Dowling to the members present, referred to the fact that this occasion was the first of what it was hoped would be a series of meetings held under the auspices of the Mining Society and the Montreal Branch.

Mr. Dowling's lecture covered a wide range, since he described in general the several great coal areas of Canada, the uses and values of the coals, and the present production in these fields. Referring to the extent of these areas, Mr. Dowling stated that the amount of coal available in the Nova Scotia, Cape Breton and British Columbia areas, also including the lignitic areas of Manitoba, Alberta and Saskatchewan represented, at a conservative estimate, a tonnage of 125,000,000,000 tons.

The lecturer, however, devoted his attention in particular to describing the coal areas of the Prairie Provinces, and displayed on the screen a number of interesting slides showing the outcrops of seams, the primitive methods employed at some of the less important properties, and other views appropriate to the subject of which he treated. Statistics were quoted to show how the production of coal in these provinces had increased and was increasing in direct proportion to the increase in population there. Another subject taken up was the difficulties of mining

in some localities. Thus, while in some mines it was possible to get a fairly solid roof, in many others it is found necessary to leave a roof of coal, and in every instance it is required to place timbers three feet apart. As timber is very scarce and expensive, it is impossible in some sections to operate mines by reason of this necessity. Again, transportation facilities are as yet very inadequate, and in many outlying localities shafts have been sunk and plants have been erected in anticipation of railway advantages being presently afforded.

Mr. Dowling was asked how the Alberta coal stood shipping. He replied that if shipped to any considerable distance it powdered, and if exposed to a dry atmosphere, the same effect was produced.

Dr. Porter stated that this coal was specially valuable for use in gas producer plants.

AT MONTREAL, APRIL, 1909.

At this meeting of the society the following officers were elected to serve for the ensuing year:

Hon. President, Dr. J. Bonsall Porter; President, Mr. C. S. MacLean; Vice-President, Max S. Archibald; Secretary-Treasurer, Mr. C. G. Porter.

The retiring president, M. H. H. Yuill, took advantage of the opportunity to express his appreciation of the loyal support he had received from members during his year of office.

EASTERN ONTARIO SECTION.

At Kingston, February, 1909.

The annual meeting of the Eastern Ontario section of the Canadian Mining Institute was held in the geology lecture room of the School of Mining, on Thursday, February 25th; the president, Prof. J. C. Gwillim, in the chair.

The student-secretary, Mr. B. R. McKay, reported that the student membership of the branch had increased to eighty-seven. Dr. Goodwin called attention to the fact that the branch was the first organized and that it would be well to see that it was officially recognized by the Canadian Mining Institute.

The election of officers for the ensuing year resulted as follows: President, Prof. J. C. Gwillim; vice-president, Prof. M. B. Baker; secretary-treasurer, John Donnelly, M.E.; assistant secretary-treasurer, E. H. Birkett.

The following papers were then read and discussed: "The Wilbur Iron Ore Deposit," by Mr. S. King; "Diamond Drill Methods," by Mr. J. K. Osborne; and "Summer Experiences of an Undergraduate," by Mr. Frederick Ransome.

A vote of thanks, on motion of Dr. Goodwin, seconded by Mr. Donnelly, was tendered to the students presenting the papers, and the meeting adjourned.

During the year a number of papers have been presented by the members, among which are the following: "Ventilation of Mountain Copper Mines," W. E. Lawson; "Gold and Silver Assaying at De Lemar," E. H. Birkett; "Mineral Resources of Nova Scotia," S. Blenkhorn; "Mineral Resources of Queen Charlotte Island," F. A. Brewster; "Arsenic Deposits of Ontario," P. J. Browne; "Ontario Mining Act," W. M. Campbell; "Helen Iron Mine," G. H. Kilburn; "Detroit River Tunnel Construction," A. G. Morrison; "Hydraulic Compressor on Montreal River," J. J. McEachern; "Iron Deposit at Bessemer, Ont.," J. N. Scott.

The Queen's branch of the Canadian Mining Institute, is to be congratulated on its increased membership, which has grown during the past year from 47 to 87. This branch can boast of having the largest student membership of any branch of the Institute, a result attributable to the energetic work of the secretary, Mr. B. R. McKay.

PAPERS

ECONOMIC GEOLOGY IN THE UNITED STATES*.

By Samuel Franklin Emmons, U.S. Geological Survey, Washington, D.C.

Having been invited by your Council to address the members of the Institute at this their Eleventh Annual Meeting, and having no new material to offer for your consideration, I have thought best to take for my subject the early development of mining or economic geology in the United States, and the relations of your older sister, the American Institute of Mining Engineers, to the Government geological work across the border, thinking that some of the experiences we have been through may be of use to our colleagues in the Dominion.

In my endeavour to trace the progress of thought in regard to questions of genesis of ore deposits, you must not think me too egotistical if what I have to say is largely of a personal nature, for in such matters one cannot to any great extent assume the right to speak for others.

When I first became connected with Government Surveys, a little over forty years ago, the people at large in the Western United States, to whom it was necessary to appeal for the means for carrying on a Geological Survey, had but little conception of the advantages and uses of such an organization, and a campaign of education of the public mind was necessary in order to demonstrate its practical value. For ten or twelve years such a demonstration was being carried on by the so-called Hayden, King, Wheeler and Powell Surveys, or geological explorations, as they might more properly have been denominated. Most of them appealed to the popular, as well as to the scientific, imagination by their brilliant discoveries of such natural wonders as the geysers of the Yellowstone, the cañons of the Colorado, and the laccolites of the Henry Mountains. The Geological Exploration of the

*An address delivered at the Annual Meeting of the Institute, Montreal, March 4th, 1909.

Fortieth Parallel, which alone planned to make a geological map of a definite and limited area, secured its appropriation from Congress on the explicitly economic ground that it was necessary for determining the character of the mineral resources of the mountainous regions to be made accessible by the recently authorized Transcontinental railroads. In furtherance of the plan of popular education, Mr. King, its organizer and chief, pushed to immediate publication the economic results of the work, the study of actually developed mines including the Comstock lode, set forth in the volume on Mining Industry which appeared in 1870, seven years before those embodying the more abstract scientific results which had to wait the completion of the researches of specialists.

The final realization of the ultimate object that the geologists of the Fortieth Parallel Exploration had in their minds during the ten years spent on that work came much earlier than had been anticipated, when in 1879 all existing geological explorations were consolidated into a permanent Geological Survey, which was organized as a bureau of the Interior Department; and there is little doubt that the practical demonstration of the utility of such work furnished by the Mining Industry volume had much effect in rendering Congress favourable to the new organization.

Mr. King, as its first director, in recognition of the legitimacy, in an industrial country like the United States, of a demand for the practical application of geology to the development of its mineral resources, established a division of Mining Geology, and devoted about half of the first year's appropriations to economic studies of mining districts, comprising the Comstock lode, the newly discovered Leadville district of Colorado, and the copper deposits of Lake Superior.

The organic law establishing the Survey had limited its operations to the National Domain, leaving it uncertain whether this meant only the Public Lands in the West still belonging to the Government, or the whole area of the United States. Until Congress explicitly authorized the former construction of the law, Mr. King's idea was by multiplying the surveys of mining districts, which involved the making of special topographic maps for each district, to demonstrate to the mining community the practical usefulness of the work, so that in time the people would

demand of their representatives in Congress its extension over the whole country. At the same time he expected that a large corps of observers, trained especially for this work, would accumulate a fund of scientific data with regard to ore deposits from which in time a new and more satisfactory theory of vein formation could be formulated, and thus confer an even greater benefit upon the mining community.

Mr. Powell, the Director who succeeded Mr. King, accomplished by indirection the construction of the law that Mr. King had failed to obtain directly. The making of a geological map is evidently the first duty of a geological survey, but this had not been explicitly mentioned in the organic law. In the paragraph of the bill making the annual appropriation for the Survey, he succeeded in having this clause inserted "and for making a geological map of the United States," so many dollars. When this had become law, he found himself not only authorized to extend his work over the whole United States, but reasoning that an indispensable preliminary to a geological map is a topographical base, he felt also authorized to have a topographical map of the whole United States constructed. As such a map of the United States would cost at the lowest estimates about thirty millions of dollars, it would evidently have been of doubtful advisability to ask Congress for it directly.

Powell did not place as much importance on mining geology as did King, and during his administration, work in this branch rather languished, topography and geology and irrigation absorbing the greater part of the Survey funds. Nevertheless, during his time Becker accomplished his investigations of the quicksilver deposits, and commenced that of the Gold Belt of California, in which he was assisted by Mr. Lindgren, while Irving and Van Hise began the study of the great iron ore regions of the North-west.

The Leadville monograph, owing to the peculiar relation of ore deposition to structural geology in that district, had served in a striking manner to illustrate the practical use of applied geology in the working of mines, and had thus served as a great educator of the miner as well as of the mining engineer, and made the work of the Survey popular. Although I was not allotted sufficient funds to undertake, during this time, the study of other great

mining districts on a similar scale, I was able, by reconnaissance studies, to keep in touch with the more important mining developments throughout the Rocky Mountain region, and by occasional articles in the American Mining Institute to keep up the interest of the mining community in the economic work of the Survey while continuing the geological education of the mining engineer.

In 1892 the Survey appropriations were cut down a third, as the result of an attack made upon the floor of Congress by the western interests that felt themselves injured by the legislation that had been brought about as a result of the Irrigation investigations carried on by Powell under the auspices of the Survey. Although the men who directed this movement were particularly friendly to the economic branch of the Survey, and had thought to benefit those who were carrying it on, their legislation had exactly the opposite effect, for this provided for the reduction of the number of chief geologists from five to two, but as the law specified no individuals, it fell to the Director to designate who should be dropped from the pay-rolls, and his choice fell upon those who had been engaged in economic work. Although we could do no official field work, Mr. Becker and I, who had been in charge of this division, continued our office work, during the interregnum.

With the appointment of Mr. Walcott as Director in 1894, the economic work of the Survey was revived and given a new lease of life. Not only were we restored to our positions, but we were allowed to recruit the force by the accession of younger men admitted from time to time by competitive examination, so that it came to include the now well known names of Ransome, Spurr, Weed, Spencer, Irving, Boutwell, Graton, and others. The field of work correspondingly widened, and was latter extended to the investigation of the non-metallic minerals under Hayes, of which, however, I shall not now have time to speak. The accumulation of knowledge under these more favourable conditions has proceeded in a sort of arithmetical progression, so that at the present time there is no important mining district in the country, of whose geological structure the Survey has not some definite knowledge, whether through special or reconnaissance surveys.

Yet, in spite of this rapid increase, the progress of education of the public, or—what amounts to the same thing—of the popular appreciation of the work, has been even greater, so that it has been

difficult to keep up with the popular demand for special economic surveys of mining districts. In one sense, indeed, this popular education has worked to our disadvantage, for the importance of a geological study of their mines is now so well appreciated by mining men that our force has been partially crippled of late years by the number of men who have left us to accept more than double their previous salaries by entering the employ of the great mining combinations as geological advisers.

Having outlined the material progress of the work, I now propose to sketch, as briefly as possible, the mental progress that has gone on at the same time, or what appear to me to have been the prominent stages in the variation of public opinion on the important phases in the theories of ore deposition. The variation in opinion on these subjects has been not inaptly compared to the motion of the pendulum of a clock, swinging for a while steadily in one direction, then halting and swinging again in the reverse direction, to change again later into the general course it took before.

It will be convenient to divide the time to be considered into periods, which may be called decades, though they are not strictly ten-year periods. The first decade extended from the creation of the Survey in 1880 to the interregnum in Survey work in 1892–94, which was marked specially by the reading of Posepny's paper on "Ore genesis" at the Chicago Exposition meeting of the American Institute. The second was from the interregnum to the Institute meetings of 1900 and 1901, at which a host of important papers were presented bearing on the theory of ore deposition, embodying generalizations from facts gathered during the economic work carried on in the two decades just concluded. The third, extending from then to the present time, will be touched upon but lightly, being too recent to afford a perspective that will permit of summarization.

This whole period of investigation forms part of what I have elsewhere called the *period of verification*, that is, a period that is characterized by attempts to test, by practical application to the facts of nature, theories or hypotheses that had already been proposed, rather than to propound new ones. This was peculiarly true of the first decade when the workers were few and they were entering upon a new field of work, their knowledge of which

was yet to be gained. The first innovation was the extending of the methods of detailed surface geological study to the subterranean areas disclosed by the drifts of large aggregations of mines. The generalizations first made were those that seemed necessary at the close of each specific piece of work, to show to the miner the conclusions deducible from the geological facts already determined, and the practical bearing they might have upon the conduct of his mining operations. For myself, in my first report —that on Leadville—while drawing what conclusions I felt justified in doing, as to what I designated the immediate source of the ores and the manner in which they had been deposited, I specifically disclaimed any intention of discussing the ultimate source from which the metals were derived, or propounding any general theories of ore deposition.

In the papers from time to time communicated to the American Institute (as part of the geological education of its members) I laid the main stress on the structural relations of the deposits, or the observed facts and generalizations bearing upon the form and nature of the rock channels through which the mineral laden waters brought in their ores. Reference was also made in these to other conclusions with a more theoretical basis, which had been criticised as novel and untenable, or misrepresented by our critics, and which we not only felt bound to defend, but often, as the result of new studies, we wanted to extend in their application. Most prominent among these were those of Metasomatism or replacement action in the formation of ore deposits, and the genetic connection of ore deposits with eruptive rocks. The former was in those early days regarded as a hobby of mine, because while all who had occasion to test it in the field were ready to admit that it, rather than cavity filling, was the process by which ores in limestone were generally deposited, when I maintained as a result of later studies that in vein deposits in the West, a very considerable portion of the vein filling is the more or less complete replacement of country rock by vein materials, rather than, as had hitherto been held, the filling of preexisting open spaces, many geologists, including my colleague Becker, seemed inclined to think I was going too far.

That eruptive rocks and ore deposits are commonly associated in nature, had been remarked on by geologists before it was

observed by us in the course of our economic studies, but in order to determine whether this connection was a genetic one, rather than merely a fortuitous association, we endeavoured to determine by careful chemical tests whether the fresh unaltered eruptive rocks contain the metals and other materials that went to make up the ore deposits we were studying, following in this the suggestion of Sandberger, who himself had followed that of Bischoff. We were hence more or less identified with the lateral secretion school that Sandberger had founded, and were assumed by some of our critics to maintain that the waters we thought had obtained their vein materials from the eruptive rocks, were cold descending waters. In point of fact, however, I by no means believed, as he did, that the vein materials were necessarily derived from the immediate walls of the deposits, and, since I showed that the deposits at Leadville had been formed under a covering of 10,000 feet of sedimentary beds, it could hardly be said that the waters that formed them were directly descending from the surface. What I did maintain was, that if, as the results of our chemical tests seemed to indicate, they were derived from cooling igneous rocks it was from such masses as had cooled within reasonable distance of the place where the deposits were found. My main point of difference with the so-called ascensionists was that they maintained that all ore deposits are formed by waters ascending from the unknown depths or the barysphere, where, owing to an assumed greater density, the rock masses must be richer in the heavy metals than those observed at the surface, which possess only about half the density of the earth as a whole. Inasmuch, therefore, as these waters were assumed by them, as by all geologists at that time and indeed until the end of the second decade, to be meteoric waters descending under the influence of gravity to rise again under the influence of heat, their assumption seemed to involve an evident impossibility. Long before these waters could reach a zone where the rocks had the requisite specific gravity, which must be many miles below the surface, they would reach a region where the pressure would be so great that open cracks that would admit of their circulation would no longer be possible, a condition that Heim in his researches on the mechanics of mountain building in the Alps had determined would exist already at a depth of 5,000 meters. It seemed more probable, therefore, that these waters had derived

their vein materials from cooling igneous masses within reasonable proximity of the surface, since chemical tests had proved the actual presence of these materials in some of the fresh rocks tested, whereas similar tests of sedimentary rocks had found none.

The chemical tests I depended on were made by Hillebrand in a laboratory which, under Mr. King's authority, I had established in Denver in 1880. In the laboratory which Becker had similarly established in San Francisco, he and Melville had made further investigations in the course of his study of quicksilver deposits, to determine the natural solvents which would have enabled the circulating waters to take up the vein materials that formed part of the rocks they were traversing.

About the middle of the decade, the chemists of both these laboratories were transferred to Washington, and the laboratories themselves soon after abandoned, so that under the pressure of other work this line of investigations was gradually dropped. Indeed until the studies of petrologists and physical chemists had thrown more definite light on the probable conditions prevailing at considerable depth beneath the surface, further speculations along this line seemed rather profitless.

Finally, in the latter part of the decade, the conclusions arrived at independently by Iddings in this country and Brögger in Norway, with regard to the differentiation in igneous magmas, showing how different varieties of rocks might proceed successively from the same deepseated molten mass, combined with the discovery that certain titaniferous iron ores in Norway were actual segregations in a cooling magma, seemed to afford a line of argument which was very suggestive and of which I made use in an article I prepared during the interregnum for the Chicago Exposition meeting of the American Institute, on the "Geological Distribution of the Useful Metals in the United States."

My line of argument was that since actual proof had thus been afforded that certain metals like iron had been concentrated in given parts of an eruptive magma, the same might be true of the other metals, though it would be less susceptible of proof on account of their much smaller proportion among the constituent minerals of rocks. Hence among the different rock-forming magmas that from time came to cool within a limited distance of the surface, and thus within reach of the circulation of meteoric

waters, it might be conceived that certain magmas, as a result of this process of differentiation, would be rich in gold and silver, others in copper and zinc, or other combinations of metals. Thus on the theory that ore deposits are the result of the leaching of bodies of eruptive rocks, one could understand why one set of deposits contain mainly one combination of metallic minerals and another another, and some regions, where eruptive rocks abound, contain little or none.

Posepny's well known article on ore genesis presented at the same meeting, while it gave an admirable description of the processes involved in ore deposition, and contained the strongest and most definite arguments yet presented in favour of the ascensionist theory, and in disproof of Sandberger's theory of lateral secretion, did not touch upon the difficulties we conceived to stand in its way from the inaccessibility of the barysphere to descending vadose or meteoric waters, though he evidently conceived of no other source for the waters circulating within the earth's crust, and was more than insistent in his belief, that practically all ore deposits have been deposited from aqueous solution, and are later than the enclosing rocks.

During the second decade my mental attitude toward these more speculative theories was still a waiting one, and I busied myself as before with those theories more capable of actual proof and of direct practical application to mining.

A question of the utmost practical importance to the mining industry and which had often been propounded without receiving any satisfactory answer, was whether vein deposits increase or decrease in value with depth, and I was most desirous of obtaining some scientific evidence in favour of either conclusion. Already in the Leadville work it had been recognized that an enhancement of values takes place in the oxidized zone, in part by removal of the baser and less valuable metals, but in part also by actual transference downward of the silver salts, but this action was supposed to necessarily come to a stop at the groundwater level.

Finally in the summer of 1896, during a study of the Butte mines, I discovered definite and unmistakable geological proof that this transference has continued for some distance downward into the zone of unaltered sulphides, thus explaining the formation of bonanzas in the middle depths of many mines, and the frequent

prevalence of low grade ore in depth beyond their reach. Appreciating at once the far-reaching practical importance of this theory of secondary sulphide enrichment, as I called it, I did not wish to publish it until I had satisfied myself as to its general applicability to all classes of deposits, and had discovered a satisfactory explanation of the apparently abnormal chemical reactions involved, which, as pointed out by Mr. King during our frequent discussions of the subject at Butte, formed the weak side of my theory. During several seasons' field work, therefore, I took every opportunity of confirming the operations of this process in other mining districts, making in 1898 a special examination of all the important copper deposits of the West, and finding a remarkable uniformity in the succession of copper minerals with depth that could only be explained on this theory. At Mr. King's suggestion, moreover, I had chemical literature searched for records of reactions that might be supposed to account for the observed mineralogical changes. Some further experimental tests in the Survey laboratory were still desired to be made, when it was announced that Mr. Weed, who had been associated with me in the Butte survey as surface geologist, was to read a paper on this subject in the winter of 1899–1900. I then learned that, prompted by suggestions gathered during our discussions on the subject at Butte in 1906, he had since been making a practical test of the theory himself in certain silver mines of Montana.

At the winter meeting (1900) of the American Institute there were read, singularly enough, beside the respective papers of Weed and myself on secondary enrichment, which presented the results of our practical studies in the mines, a more theoretical discussion of "Some Principles Controlling Deposition of Ores," by Prof. Van Hise, in which independently and from a somewhat different point of view, he had arrived at practically the same conclusions that we did with regard to the secondary enrichment of sulphides by descending waters.

Van Hise's article contained an admirable exposition, founded on careful experimental studies, of the manner in which meteoric waters circulate within the crust, and cleared up many points left uncertain by Posepny's earlier explanations, but like him he considered the vast majority of deposits epigenetic, and formed through the agency of meteoric waters, practically ignoring, as

Lindgren later pointed out in his article on contact metamorphic deposits presented at the Richmond meeting, the important contact deposits of the Kristiania type. It is true that up to 1900 none of us, except possibly Mr. Lindgren himself, had given as much attention as was deserved to this class of deposit. The Kristiania deposits, and indeed most of those in Europe and elsewhere, that had been recognized as belonging to the same type, were of little economic importance, and regarded rather in the light of mineralogical curiosities. It is only from 1900 that dates the recognition that many important workable deposits, especially of copper, belong to this class, and, after all, in economic geology actual commercial value is the standard by which we fix the relative importance of different types of deposits.

The most decided reaction against the Van Hise-Posepny view presented at the Richmond meeting (1901) was contained in Prof. Kemp's article on "The rôle of igneous rocks in the formation of ore deposits," in which he ascribes the principal rôle not to meteoric waters, as Van Hise had done, but to waters proceeding from the igneous rocks themselves, hence called magmatic waters. In addition to his forcible theoretical arguments in favour of magmatic, rather than meteoric waters, as conveyers of vein materials, Prof. Kemp quoted several facts of observation showing that the bottom levels of deep mines are generally found to be dry, and hence argued that meteoric waters do not penetrate to depths of over two or three thousand feet, consequently could not act as conveyers of vein materials from the depths. Kemp's contention received unexpected support from an announcement by the great Austrian geologist Suess at a Balneological convention at Karlsbad in 1902. In his address Suess stated his belief that the waters of certain thermal springs of Europe, which have long been the subject of careful chemical study, are derived not from descending meteoric or vadose waters, but have their source in cooling eruptive magmas, and as they reach the surface for the first time in these springs he denominated them *Juvenile* waters. To this origin he ascribed the vapours poured out by active volcanoes, which had hitherto been supposed to be fed by sea waters percolating downward through the rocks and meeting the uprising lava streams. Springs then, he classified, by the source of their waters, as Juvenile and Vadose, and those that are fed in

part by waters from both sources. A certain amount of verification of these views is found in the permanence of composition of the springs classed as Juvenile, and their independence of variations in the amount of precipitation in the surrounding regions.

Kemp's views were in the same general line, though a step in advance, of the views maintained by the Norwegian geologist Vogt, who since 1893 had been advocating a constantly widening applicability of magmatic or pneumatolytic origin to ore deposits, and whose views had been adopted by a number of geologists on this side of the water. Hence Kemp's article met with very general favour.

That, among those who are ready to accept the prevailing theory, whatever it may be, for the explanation of the ultimate origin of the deposits they may have occasion to study, this latest explanation has met with such universal acceptation, is hardly surprising. If accepted it removes at once all the objections that have heretofore obtained against either the ascension or lateral secretion forms of theory. It is a return to the Catholic faith of the earlier days, as far as the source of the metals in the unknown depths is concerned, a faith that has been strengthened and rendered more specific by such positive evidence as has been obtained with regard to thermal springs, and the negative evidence of the aridity of such deeper parts of the crusts as have come within the range of direct observation.

I will not trespass upon your time and patience by discussing the *pros* and *cons* of the modern popular theory of the magmatic origin of all ore deposits, with regard to which I can claim no greater familiarity than you. I fully admit its attractiveness as a method of removing the obstacle to deep circulation presented by increase of pressure with depth, since if the *vis a tergo* is sufficient to force up molten lavas across the zone of flowage, the same force ought to suffice for aqueous solutions.

One of the points on which I still maintain a doubting position, however, is as to whether we have any definite proof that magmas contain enough water to afford the continuous flow needed to supply thermal springs as well as ore deposits. The study of contact metamorphic deposits has afforded some definite proof that certain magmas have given out aqueous solutions,

whether in gaseous or liquid form is not essential, that have actually contributed to the surrounding rocks supplies of metallic minerals, but this action was geologically brief, and differs from that involved in affording the continuous supply from great depths predicated by the conditions that obtain in thermal springs, or in the greater accumulations of metallic minerals such as Leadville, Butte, etc.

Before we can assume the sufficiency of this source for subterranean waters we must await further developments from the profound and necessarily deliberate labours in the realm of physical chemistry such as have been and still are being carried on by Prof. F. D. Adams in this city, and by Becker, Day, and Wright at Washington, and the results of more such searching geological investigations, as those of Lindgren, on the contact metamorphic deposits of Clifton-Morenci.

You Canadian geologists have a vast and intensely interesting field of work, the complete covering of which must for a very long period yet be practically impossible, owing to inadequacy of the pecuniary means your legislature may be able to allow you.

Permit me to suggest then, that rather than attempt to cover superficially too wide an area, you devote your energies rather to an exhaustive study of a few important mining districts. The definite and authoritative results that may be obtained from one such study are worth more than those derived from a host of personal examinations, which must necessarily be more or less in the nature of individual opinions.

METALLOGENETIC EPOCHS.

By WALDEMAR LINDGREN, Washington, D.C.

(Annual Meeting, Montreal, March, 1909).

The difficulties of a student of mineral deposits are increasing. As in petrography the first descriptive period of the science is drawing to a close. We know the principal types, and, though much remains to be done in detailed accounts, it seems that we are gradually coming to the same "impasse" which confronts the petrologist, who is now turning to the exact experiments of physical chemistry for the solution of the riddles which confront him. And as we transfer some of our most important problems into the same able hands for experimental work at high temperatures and pressures, some of us may confess to a slight feeling of disappointment that inductive work has failed to furnish definite answers to many of our questions. But such a state of mind should only be like the shadow of a passing cloud; for the study of mineral deposits is not a science distinct from others; it leans on all branches of geology as well as on chemistry and physics, and this new development means not only that we have taken a step in advance; that we have acquired a new and powerful collaborator; it means also still further specialization. It does not mean that the scientific services of the mining geologist will be unnecessary or futile. His work will be necessary to assemble and assort the facts, to test the results of the laboratory, to propound new problems, and to generalize from the study of wide areas.

This critical examination of mineral deposits over wide areas is a work which now confronts us. It is the geographic and historical side of our science. With some hesitation I venture to place before this Institute an epitome of the principal epochs of the segregation of metals over our continent. Many of the facts are well known to you and the only feature of this paper which can

possibly merit your attention is the summarizing of these well known facts.

This continent of North America is rich in metallic wealth; its total production exceeds that of any other equivalent division of the earth. Gold and silver come from the Cordilleran belt and also from the eastern margin of the continent. Copper in ever increasing quantities is derived from the Central Basin and from deposits in the west extending from Sonora to British Columbia. Lead and zinc are produced from our vast Mississippi basin and from the ranges of the Rocky Mountains. Half of the world's nickel is drawn from Ontario and a large part of the tungsten comes from Colorado. The total value of the metallic product of the continent in 1908 was about $1,000,000,000.

In some measure we have succeeded in classifying the vast number of deposits, not only with reference to their mineralogical and structural characteristics, but also with reference to their age. We find that metalliferous deposits have been formed since the earliest times of geological history. We find also that they are not equally distributed over the continent, but occur in metallogenetic provinces of greatly differing form and extent. Moreover, these metallic concentrations have not been going on at equal rates throughout geologic time, but the formation of each group corresponds to a fairly brief epoch which, with few exceptions, is also an epoch of vulcanism. No fact is better established than this, however much we may differ in details of genetic history. On the other hand, regions of vulcanism do not necessarily contain ore deposits. Naturally we find the ores in regions of uplift and erosion, for here the rocks are best exposed, but they are not necessarily connected with such warpings and corrugations, as is illustrated by the oft-cited poverty in metalliferous deposits of the Appalachian ranges of sedimentary rocks.

Since the earliest times, then, metallogenetic epochs have recurred on the North American continent, and, comparing it with others, we must conclude that either the original sources from which the ores have been concentrated have been richer than elsewhere or the conditions for their formation have been more favourable than elsewhere.

In describing these epochs it will be convenient to separate the eastern and the western halves of the continent for,

with exception of the earliest part of their history, they have little in common.

EPOCHS OF ORE DEPOSITION IN THE EASTERN PART OF THE CONTINENT.

1. *The Pre-Cambrian period.*—The Pre-Cambrian period embraces a very long time and many differing epochs of ore formation; but for our present purposes it will be necessary to consider it as a whole. Ages of sedimentation alternated with violent igneous action. At many places long erosion preceded the deposition of the Cambrian. The Pre-Cambrian deposits form a belt along the southern Appalachians, extending northward into Canada, where they are found over a wide area. They occupy parts of Michigan, Wisconsin, and Minnesota, and re-appear in the west, in South Dakota, Wyoming, Colorado, New Mexico and Arizona; possibly also in south-western California, but with less of the diversity characterizing the Lake Superior region. In the latter region there is a great succession of igneous rocks, effusive as well as intrusive, ranging from granites to basalts, diabases and gabbros. In the Cordilleran region the intrusives are almost exclusively represented and the prevailing type is the normal red granite contrasting strangely with the later intermediate type of intrusives. Smaller amounts of intrusive diorite, gabbro and diabase are present.

The metals characteristic of this period are iron, copper, nickel, gold and silver. Lead and zinc appear to be present in far smaller quantities than in later periods. Quicksilver and antimony are rare. The iron ores are, as well known, of several types: the ilmenites and the magnetites are chiefly of igneous origin: the hematites of Lake Superior, according to Leith, of partly igneous, partly sedimentary origin, and ultimately oxidized and concentrated by surface waters. It is believed that this concentration took place mainly in Pre-Cambrian time. The copper and nickel ores are connected with basic igneous rocks, in part intrusive, in part, as in the Michigan copper region, of effusive type. The concentration of the copper of this latter region into workable deposits also seems to have taken place chiefly, if not wholly, in Pre-Cambrian time, and probably followed the close of the igneous

activity in Keweenawan time. The silver veins of Cobalt, which have proved so rich, are likewise Pre-Cambrian and some writers are inclined to connect them with Keweenawan basic intrusives into Huronian rocks.

In the Southern States the deposition of the gold-bearing quartz veins in most cases directly followed granitic intrusions in various sedimentary schists. The assertions of earlier writers, that these veins are genetically connected with basic intrusives, are not supported by recent work. Some silver and copper are associated with these gold-bearing veins. It should be added that some writers assign a Cambrian or even later age to the southern granites. Minor copper deposits in the same region are chiefly derived from intrusions of diabase or allied rocks. Pre-Cambrian gold-quartz veins are also known from Western Ontario.

2. *Epoch of Paleozoic intrusives.*—From New York and New England northward into Quebec and Nova Scotia granitic intrusions took place at various times during the Paleozoic as late as the carboniferous and were accompanied by some metallization. The gold-quartz veins of Quebec and Nova Scotia were in part, at least, formed after these intrusions and various small deposits in New England have a similar origin.

3. *Epochs of the Sedimentary iron ores.*—Processes of sedimentation under favourable conditions lead to concentration of iron ores. During the long period of unbroken Paleozoic sedimentation in the Appalachian region there were at least two epochs which are characterized by such iron ores. During the Clinton stage of the Silurian, persistent beds of low grade hematite were formed; and during the Carboniferous less important layers of carbonate black band ores were deposited.

4. *Epochs of the Triassic traps.*—The important period of the history of the igneo-genetic ore deposits of the eastern part of the continent closed in the late Paleozoic and the majority of these deposits had been formed much earlier. A feeble recurrence of ore formation took place during the early Mesozoic, when the traps of the Eastern States were injected as sheets or overflowed as lava streams. Smaller masses of iron and copper ores developed along the igneous contacts, in part as veins, in part as contact metamorphic deposits.

5. *Cretaceous, Tertiary, or later epochs of zinc and lead concentration.*—Since the Triassic, vulcanism has rested and in the eastern part of the continent metal deposits have formed only by the concentrating power of flowing surface waters or of groundwater in decaying rocks, or of ascending waters of atmospheric origin.

In the central valleys, such ore concentration has been effected in comparatively late time, apparently independent of vulcanism, and has resulted in the most important lead and zinc deposits on the continent. Regarding the mode of origin of these deposits opinions differ widely, but most observers believe that the lead and zinc has been leached by surface waters from Paleozic limestones which derived their sparsely disseminated content from the pre-Cambrian northern continent. Some regard the process as a simple affair of downward percolating surface waters. Others attribute it to vigorous ascending circulation of atmospheric origin. The time of this concentration is thought to range from the establishment of a circulation dependent upon uplift, perhaps from the Cretaceous to the present time but some geologists have not hesitated to say that ore concentration began in late Paleozoic or in Mesozoic time. Further discussion cannot be attempted here, but with reference to the theories just indicated it may be worth while to point out that lead and zinc deposits are very scarce in pre-Cambrian rocks and the latter would hardly seem to be an adequate primary supply. There is undoubtedly much evidence in favour of concentration by ordinary surface waters, but the lead-zinc deposits in Kentucky and Arkansas certainly show transition into types, which closely resemble western types of veins, attributed to hot waters. The ores in the more important districts appear to convey the impression of sharply defined depositional epochs, rather than of long continued action of cold waters descending from the surface.

EPOCHS OF ORE DEPOSITION IN THE WESTERN PART OF THE CONTINENT.

The metallogenetic history of the Cordilleran region is more complex than that of the eastern half of the continent, but it is in some respects easier to interpret.

1. *The Pre-Cambrian period.*—The Pre-Cambrian period, as already mentioned, was productive of gold and copper deposits scattered from South Dakota through Wyoming, Colorado, New Mexico, and Arizona. South and west of this area the Pre-Cambrian is lacking; north of it, these old formations are present in places, but appear to contain no ore deposits formed during that period. In the Black Hills of South Dakota and in New Mexico some deposits referred to this group have been clearly shown to antedate the Paleozoic and others in Arizona give strong inferential evidence of as great geologic age.

The pre-Paleozoic gold deposits are generally lenticular quartz veins in schists, associated with heavy gangue minerals like tourmaline, garnet, etc. The copper deposits which usually contain chalcopyrite, are veins or irregular masses, the latter often of magmatic origin, but modified by dynamo metamorphism. Zinc blende is sometimes found with the chalcopyrite. Lead is almost wholly absent.

Throughout the Paleozoic, and the larger part of the Mesozoic the great interior province, now occupied by the Rocky Mountains, was the scene of almost uninterrupted sedimentation. Land areas existed here and there, but the igneous forces, so active over the whole country in pre-Cambrian time, were quiet for ages.

Not so along the Pacific coast; for here we find in places evidence of intrusions and lava flows dating back to the early Paleozoic. As yet it has not been shown that mineral deposits of that date exist along the coast, except in the Copper River region of Alaska where copper ores are contained in greenstones of Carboniferous age; here as elsewhere it is probable that metallization took place shortly after the eruption.

2. *The early Mesozoic epoch.*—Between the Carboniferous and the Triassic, uplifts and folds had raised the Paleozoic sediments and the early Mesozoic beds were deposited unconformably on the older rocks. Some time during the Triassic an epoch of intense igneous activity began and continued through the Jurassic. Basic lavas, mainly of the types of diabases and andesites, were erupted, largely as volcanic flows, from California to Alaska. A distinct epoch of metallization, principally yielding copper deposits, accompanied or followed these eruptions. We shall not err greatly in ascribing some copper deposits of California, and British Columbia,

to this, the second metallogenetic epoch definitely recognized on the Pacific coast.

3. *The late Mesozoic epoch.*—The third and most important epoch followed the intrusions of the great batholiths of the Pacific coast to which an early Cretaceous age is generally assigned. These intrusions of intermediate quartz-monzonitic or granodioritic character took place upon a scale difficult to grasp in its immensity. The present exposures show two main granitic masses, possibly connected beneath the Tertiary lavas. The southern batholith extends through California, the northern batholith stretches from Washington up through British Columbia to Alaska. Another smaller mass now occupies the central part of Idaho. Innumerable intrusives of less volume broke through the crust in Southern California, Southern Arizona, Western Nevada, Oregon, and elsewhere. The age of the batholith of Western Montana is somewhat in doubt, it may belong to a later epoch. But throughout this revolution and the birth of the mountain ranges on the coast, the Cretaceous was being quietly deposited at sea level all over the eastern Cordilleran region.

An epoch of intense metallization followed these intrusions, within the areas indicated. The great interior masses of the batholiths are usually free from deposits, as shown in the High Sierra, in the Clearwater region, and in British Columbia. But along their margins mineral deposits formed in abundance, as along the gold belt of California, and along the two contacts of the batholith of the Canadian and Alaskan coast regions. The latest researches by the Alaskan division of the United States Geological Survey indicate that the great placer fields of Alaska derived their gold from deposits of this epoch. Gold, primarily, and copper, secondarily, are the characteristic metals. Along the Pacific coast, where there is little limestone in the intruded sediments, lead is practically absent, but in the interior, as in Nevada and Idaho, where the intrusions came into contact with Paleozoic limestone, this metal, with zinc, begins to appear. Silver is everywhere present, but scarcely ever important, except where lead appears. Arsenic and antimony are not abundant, mercury is nowhere present in commercial quantities.

4. *The early Tertiary epoch.*—As if exhausted, the igneous forces appear to have rested until the close of the Cretaceous and

then broke out in a new field, along the eastern margin of the Cordilleran region, at that time largely covered by a plastic mantle of of Cretaceous shales and sandstones, several thousand feet in thickness, which rested on great accumulations of Paleozoic limestones.

The predominating magmas were again of intermediate character, and solidified as granular or porphyritic rocks, standing between the granites and the diorites; they contrast markedly with the potassic and acidic magmas of pre-Cambrian times. While it is not necessary to limit strictly this igneous activity to a certain time, there is little doubt that most of it took place in the Eocene. The eruptions mainly took the form of intrusions and largely that of laccoliths, undoubtedly because, unlike the conditions of the shattered rocks of the Pacific coast, they were covered by this heavy, tough and still yielding mass of Cretaceous sediments. We find an enormous number of these intrusions as sheets or laccoliths at various horizons between the Cambrian and the Cretaceous or as dikes or stocks that break through the underlying pre-Cambrian. They are rarely comparable in extent to the great batholiths of the coast. They occur from British Columbia, through Montana, Colorado, New Mexico, eastern Arizona, and probably attain their greatest development in eastern Mexico. For reasons already indicated many, perhaps most, of these intrusives never reached the surface. Only in a few cases, as in Montana and in Colorado, near Denver, do the strata of Laramie or Eocene age contain volcanic detritus.

The third Cordilleran epoch of metallization followed these intrusions; contact metamorphic deposits and veins were formed in abundance around their margins. The characteristic metals are silver and gold with much lead and zinc, especially where the intrusions cut the limestones. Copper and iron are also present at such limestone contacts. Arsenic and antimony are far more in evidence than during the second epoch, but mercury is still absent.

5. *The late Tertiary epoch.*—Orogenic disturbances followed the intrusions; the whole Cordilleran region was lifted high above sea level, warped, and faulted. These disturbances may have facilitated sub-aerial eruptions; at any rate it is certain that the middle and close of the Tertiary witnessed outflows of lavas upon a magnificent scale.

These eruptions spread over large areas of the western part of the continent; less pronounced in British Columbia and Alaska, they are abundantly represented in California, Washington, Oregon, Idaho, Colorado, Utah, Nevada, New Mexico, Arizona, and attained their greatest development in Mexico. Andesites and rhyolites are the predominating rocks. In some places the flows attained such thickness that during the later part of the volcanic epoch intrusions of magmas consolidated in them with granular structure.

During these eruptions, not strictly contemporaneous throughout, a fifth metallization took place, of which the characteristic metals are gold and silver. These deposits were often of great richness which is further accentuated by secondary processes; in fact most of the "bonanzas" belong to this class. Lead and zinc are not conspicuous except where the metallization took place in limestone. Copper is not abundant. Tellurium and antimony are common. Not that they are absent in older metallizations, but they, especially tellurium, seem particularly characteristic of this epoch.

Large areas of volcanic rocks are barren. The metal deposits seem to have formed only near or at the foci of igneous activity, where connection could be established with underlying magmas. The most recent eruptions were mainly basalts, and these, except in one case, do not seem to have been affected by metallization.

6. *The Post-Pliocene epoch.*—The youngest metallogenetic province is that of the Pacific coast line. It is of very late age — Post-Pliocene apparently, and is characterized by mercury accompanied by few other metals. It developed in the Coast Ranges of California, following basalt eruptions and contemporaneous with it was a great development of hot springs. In part the deposition goes on at the present time.

Note that the quicksilver did not develop simultaneously with the birth of the coast ranges; these are much older, and an active circulation of atmospheric water was undoubtedly established long before the quicksilver deposits were formed.

7. *Cretaceous or later epochs of copper concentration in Sedimentary rocks.*—In addition to these six classes, whose connections with igneous rocks are indubitable, the disseminated copper ores of the south-west should find mention. They occur in sandstones,

shales, or conglomerates ranging from the Carboniferous to the Cretaceous, and, in most cases, chalcocite is the primary ore; frequently small amounts of silver are present. New Mexico, Arizona, Utah, Colorado, and Texas offer numerous examples of this class. While their origin is not wholly clear, many observers believe that they represent concentration by groundwaters of small amounts of copper originally derived from the pre-Cambrian deposits and since distributed through late sedimentary beds.

Summing up we have then in the Cordilleran region: —

	Principal metals	Principal rocks associated with deposits
1. Deposits of the Pre-Cambrian period	Gold and copper	Granites, Diorites, gabbro
2. Deposits of the early Mesozoic epoch	Copper	Basalt, diabase, Gabbro
3. Deposits of the late Mesozoic epoch	Gold	Granodiorite, Quartz-monzonite
4. Deposits of the early Tertiary epoch	Gold, silver Copper, lead, zinc	Granodiorite, Quartz-monzonite Monzonite with corresponding porphyritic rocks
5. Deposits of the late Tertiary epoch	Gold, silver	Andesite, Rhyolite
6. Deposits of the Post-Pliocene epoch	Quicksilver	Basalt
7. Cretaceous or later concentrations in sedimentary rocks	Copper	Sandstone, shale, Conglomerate

As the surface of the earth is brought near to any deposit by the erosion of covering rocks, the chemical action of descending oxygenated groundwaters, finally also the transporting activity of running waters, are brought into play. Enrichment by simple oxidation or by the formation of secondary sulphides may then take place. Migration of metals into adjoining rocks may also follow. The heavy indestructible minerals will be sorted out and accumulate in the gravels of adjoining streams. In short, each primary deposit may be the parent of several of secondary grade, and the latter are usually the richer. But the secondary deposits

cannot be classified on the same basis as the primary, for groundwater and surface streams may at the same time attack deposits of widely differing age, and, under favourable conditions, such secondary migrations may be in progress at a given primary deposit for long periods of geological time.

Several observers have noted that the character of metallization appears to vary with geological time. In the above summary, this is illustrated by the almost exclusive appearance of important quicksilver deposits in recent epochs. Others have laid emphasis on the varying depth below the surface at which the deposition took place, maintaining, for instance, that, because certain sulpho-salts of quicksilver are easily soluble, they would remain in solution in the ascending waters until the surface had nearly been reached. Neither view, probably, contains the whole truth. It is evident, for example, that many deposits of gold, silver, and other metals have been formed near the surface in volcanic regions, in which quicksilver is wholly absent.

In deposits that are clearly connected with igneous rocks metallization is certainly a function of varying pressure and temperature; these factors being dependent upon depths below the surface and other conditions; metallization is also dependent on the nature of the rocks in which deposition takes place. Primarily, however, it is probably a consequence of magmatic differentiation.

It is well established that magmas of different types contain different associations of the rarer metals. For instance, tin and tungsten characterize acidic rocks, while nickel and cobalt are found chiefly in magmas rich in ferro-magnesian constituents. At the same time rocks of a given general composition may, in different localities, vary considerably in the quantity of rarer metals contained.

Our knowledge of the content of rarer metals in igneous rocks is fragmentary, but it is at least often the case that ore deposits formed after the eruption of an igneous rock will contain the rarer metals characteristic of it. It may be true that for each differentiated rock type there are corresponding types of deposits, varying with the conditions of deposition.

As periods of long continued differentiation may materially modify the composition of a magma, it is conceivable that this

might find expression in a progressive change in the character of ore deposits successively formed during these periods. The quicksilver deposits of California, for instance, may be the ultimate result of such long continued differentiation.

Perhaps it may be thought that the limits of epochs of metallization have been drawn too closely in this paper. It is freely admitted that in many cases there may be room for doubt. But if this opening of the question will stimulate discussion of a vital subject it will have achieved its most desired result.

MICHIGAN IRON MINES AND THEIR MINE WATERS.

By ALFRED C. LANE, State Geologist, Lansing, Mich.

(Annual Meeting, Montreal, March, 1909.)

In speaking of some interesting mine waters from our Michigan Iron Ranges, it will make the object of such studies clearer if one begins with a brief general description of the ores and the theories of their origin, even though in this one trespasses somewhat upon the field of Leith,* who is much more familiar with this field than the writer, whose studies have been more in the copper bearing rocks. To Leith and to his friend and co-worker Prof. A. E. Seaman of the Michigan College of Mines, as well as to Van Hise, Smyth and others, the writer would express thanks and acknowledgements.

THE SUCCESSION OF THE IRON BEARING ROCKS.

Of iron bearing rocks, similar to the Vermillion Range rocks and older than the Huronian there is not very much trace. Still in the Greenstone schist or Keewatin series around Marquette, there are some cherty and jaspilitic bands which may be compared with the Vermillion rocks. These old Greenstone schists are also often full of granite interleaved and interlaced in the fashion which has suggested magmatic stoping. The granites many would call Laurentian. In nomenclature I shall follow the geological section which Seaman and I prepared.† (See Figure).

Above this comes the Huronian and it seems possible to see in this by a little straining, a tendency toward three of Newberry's cycles of sedimentation. Call the three divisions Eo-Huronian, Mio-Huronian, and Neo-Huronian to avoid confusion with the earlier dual division, and in two of these there is on top

*See especially his paper in the Transactions Am. Inst. M.E. (1906.) XXXVI, pp. 101–153.

†Notes on the Geological Section of Michigan. Part I. The Preordovician by A. C. Lane and A. E. Seaman. Journ. Geol. XV (1907), pp. 680.

a sedimentary black slate formation. Then beneath there is a chemical precipitate, a dolomite, chert, jaspilite, taconyte, or similar formation, passing back at the base into a klastic quartzite or conglomerate formation. Volcanics were poured forth as effusive lavas and tuffs in various stages and they cut the beds also extensively in dikes and sills. They are much more commonly femic, and though originally largely augitic are now mainly uralitic. Granitic or porphyry intrusives or effusives occur, but are rare. Peridotites and serpentines occur. If now we can somewhere find a black slate above the Negaunee formation, which has almost everywhere been eroded the parallel will become much more exact, and the cycles perfect. This may quite possibly be done, for it must not be forgotten that each of these series is separated from the other by unconformities indicating a period of erosion. The Wewe slate at the top of the Eo-Huronian only rarely remains. The Animikie black slate is entirely eroded from the Gogebic Range north of Sunday Lake. On the Gogebic Range the entire middle series and most of the lower seems to be absent. More careful studies of the future may identify a black slate top to the Negaunee formation, possibly some part of the Mansfield slates. Indeed some facts told me by H. Fesing would point to such a conclusion, and Prof. Seaman thinks it quite possible.

While this triple division into three cycles with three parts each is of use, at least as an aid to the memory and, to one who believes, like the writer, in the probable world-wide character of these cycles, as an aid in correlation, one may not press the parallel too far. The black slate formation seems to be much better developed in the uppermost of the three, and banded chert and iron ore (jaspilite) in the middle, while the chemical* precipitate middle member of the lowest series is quite different from those in the upper two members.

This great dolomite is wide spread and persistent. It is the Kona, Randville, and Bad River on the Marquette, Menominee and Gogebic Ranges respectively. It is easily identified in the Garden River limestone of the original Huronian area just east of Sault Ste. Marie. In Michigan it seems thicker and more conspicuous to the east. One is strongly tempted to believe that it

*Or possibly organic, like the bog lime marl of the cement factories.

is no other than the Grenville limestone, lying on the Keewatin, and the recent work of Adams, Miller and Knight tends to confirm the suggestion. There is, however, an enormous discrepancy in thickness.

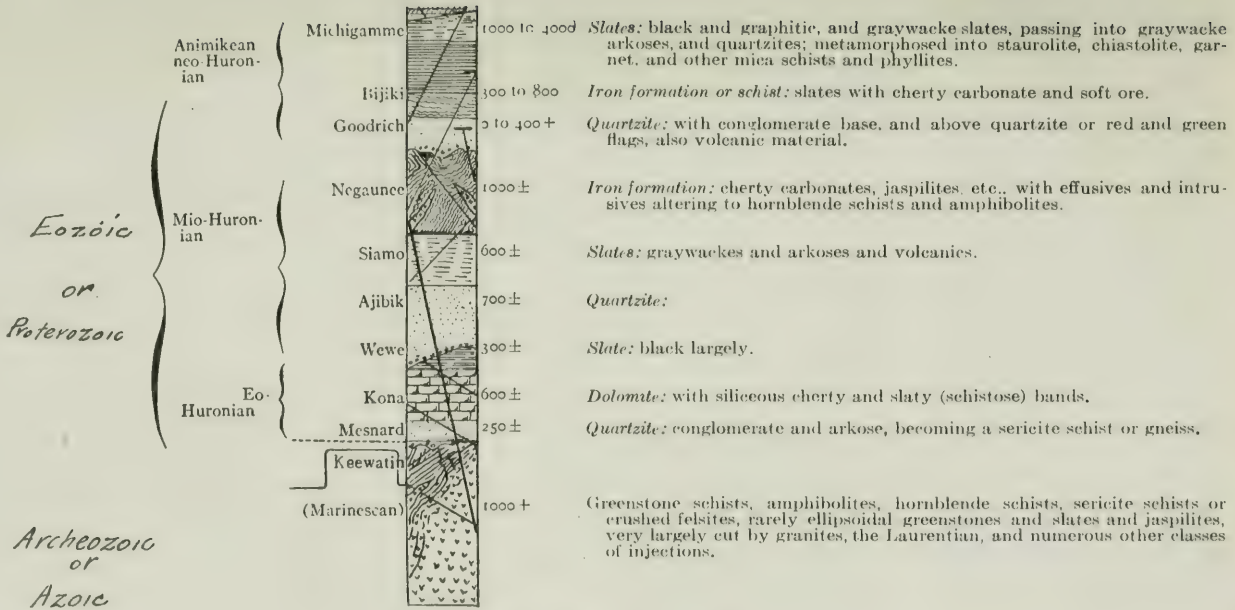
The names of the different formations used in the figure are those given in the Marquette Monograph. But as studied on other ranges they have received other names. As we have three series in the Huronian, each with three formations, so for memory's sake we may distinguish three ranges. On the west the Gogebic, on the northeast the Marquette, and on the southeast the Menominee. But this is only rough. Between the Gogebic and the Menominee comes the Crystal Falls district. Between the Menominee and Marquette the Metropolitan or Felch Mountain, Princeton or Swanzy, and Cascade ranges. North from Marquette lies the iron ores of the valley of the Yellow Dog, and west toward Gogebic once more the Republic trough and the region of the Taylor mine are covered with Huronian rocks.

It may be useful also to have a summary comparative table of the names applied to the formations on the various ranges. It is as follows:—

Range	Marquette	Menominee	Gogebic
Neo-Huronian	Michigamme	Hanbury	Tyler
	Bijiki*	Curry†	Ironwood
	Goodrich		Palms
Mio-Huronian	Negaunee	Brier	Unconformity.
	Siamo	Traders	
	Ajibik		
Eo-Huronian	Wewe		
	Kona	Randville	Bad (River)
	Mesnard	Sturgeon	

*The Curry, Brier and Traders have been grouped together as the Vulcan.

†The Bijiki and Goodrich taken together are called Ishpeming. The Hemlock of Crystal Falls and Clarksburg of Marquette are series of surface volcanics intercalated in the neo-Huronian.



Huronian Section in Michigan.

Referring to a map for the more exact location, we may represent key names in type schematically as follows: -

		Dead River	Cascade
		Yellow Dog	Marquette
	Taylor Mine		Princeton or Swanzy
Gogebic		Republic	Metropolitan or Felch Mountain
	Watersmeet		
		Crystal Falls	Menominee to Green Bay.

While for simplicity's sake, in brief review, we have left out of consideration the volcanics, we must now emphasize them all the more. They are the source directly or indirectly of the iron ores, as Leith and the writer would agree. The Greenstone schist, Keewatin, consists mainly of basic volcanics. But in the Siamo slate and in the Animikie (neo-Huronian) the Clarksburg and Hemlock formation are extensive intercalations of surface volcanics. The next succeeding epoch, the Keweenawan, is one of pronounced volcanic activity, and dikes which from their fresher, less uralitic character are correlated with it, also cut the iron bearing rocks, and especially on the Gogebic range seem to have had much to do with determining the ore bodies. Thus, very common around the iron ores are basic rocks and altered basic rocks known by a variety of names, diabases altered to kaolins, sericite schists and paint rocks by one line of alteration, to uralite diabases, and then amphibolites or epidiorites (commonly called diorites), hornblende and chlorite schists and paint rocks by another line of alteration.

While most authorities agree that the basic volcanics are the sources of the iron ores,* there is great divergence in the opinions as to how the iron ore has been collected. Most of the authors would, however, agree that it may have been concentrated in more than one way, and that probably in some cases more than one method of concentrations has had its effect.

If, therefore, I tag each different method with the name of an author, it is merely because an author has very fully or ably or conveniently stated that particular method of concentration.

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*Dr. M. E. Wadsworth and Whitney considered the jaspilites to be acid volcanics. N. H. Winchell has recently (Proc. L. S. M. I. XIII, p. 203) suggested that the taconyte is volcanic, but presumably basic.

In this connection the very instructive tables prepared by Leith for the St. Louis Exposition should be consulted,* and his paper before this Society last year.**

1. In some cases trap dikes have been leached to kaolinite and the iron oxide removed which may have been precipitated to help make the ore bodies.

For instance, Patton describes such an alteration in a dike near the lake shaft of the Cleveland mine, Ishpeming.†

The following analyses of the fresh and altered rocks speak for themselves:—

	No. 13,456	13,459
SiO_2	47.99	58.22
Al_2O_3	16.57	28.66
Fe_2O_3	6.01	2.56
FeO	5.13	0.22
CaO	9.36	.....
MgO	6.01	.....
MnO	tr.	.....
Na_2O	2.00	.....
K_2O	1.39	.....
TiO_2	2.71	.....
H_2O	2.64	10.50
	99.90	100.33

Van Hise and Irving give analyses showing an identical transformation on the Gogebic range.

But such alterations are not the sole sources of iron concentration, because we find banded jasper iron ore (jaspilite) pebbles in conglomerates older than these dikes.

Such an alteration is probably due to descending waters, analogous to the production of bauxites and lateritic iron ores at the present day—well brought out in Maxwell's studies of the soils of the Hawaiian islands.

2. I have also‡ called attention to the fact that in the formation of amphibolites and hornblende schists there seems to have

*Proc. A. Inst. Mining Engineers, Volume 36, p. 134–135.
**Journal Canadian Mining Institute, 1908, pp. 96.
†Report Michigan Board of Geological Survey, 1893, pp. 141, 185, 186.
‡Same report for 1893, pp. 180–181.

been a loss of iron, and suggested that the iron thus removed was concentrated into ore, being removed by alkaline solutions which formed with the iron double salts precipitated where they reached an oxidizing agent and that these solutions may have been upward working and cooling, a sort of earth sweat. I do not think this suggestion of mine applies anywhere to any great extent, and quite likely nowhere really explains an ore body. But it is worth mentioning for completeness and because it is one theory which can be tested by considering the character of mine waters.

3. The basic rocks and tuffs may have been leached almost at once, if land formations, or lifted up during Huronian time and the iron deposited as bog iron ore, limonite, just as it is deposited to-day beneath our peat bogs. This is Weidman's theory for the Baraboo range. Then later it would be dehydrated, forming the iron ores directly with no further concentration.

4. Irving and Van Hise were, however, inclined to look upon a cherty iron carbonate as the first form precipitated, which was later acted upon to form the ore bodies, by the leaching of descending waters.

5. Spurr, in studying the Mesabi range ores found certain round grains of ferrous silicate which he called glanconite, and Leith (since there appears to be no potash in them) calls greenalite. These may well be of organic origin, and he has hence inclined to infer that this was the original form of ore. He would agree with Irving and Van Hise as to the secondary concentration of the ores and enrichment by downward leaching, which is indeed obvious beyond reasonable question on the Mesabi range.

7. Again there are cases, of which the Helen mine is the most notable, where the development of the iron ore bodies from the leaching of sulphides as an exaggerated "iron hat" is beyond question, and this has been well described by Coleman and Willmot.

We have not yet exhausted all possible and probable methods of transporting and collecting the iron.

8. My predecessor, Dr. M. E. Wadsworth, at one time ardently advocated the idea that the more important iron ores were essentially of igneous origin, more or less changed by percolating waters to be sure; that they were comparable to some extent with iron mountain of Missouri, and were an iron bearing rhyolite which he called jaspilite.

This view is now generally abandoned. The intrusive contacts which seemed to him convincing proof of this view turn out to be explicable as contacts with green, slaty phases of altered intrusives, the other rock, not the jaspilite, being intrusive, though at times the appearances are very deceptive. The jaspilites are never porphyritic, and cherty beds occur regularly at certain horizons passing into banded beds and slates in a way inconsistent with igneous origin.

9. Quite recently my friend, Prof. N. H. Winchell, has observed facts that led him to suggest* once more that the Mesabi iron formation was "analogous to the Keweenawan," altered "remnants of original basic greenstones, and thick beds of conglomerate composed of the same rock as that of the associated strata." With this view, too, I must entirely disagree. I have been over the ground with him and for twenty years have been studying the Keweenawan rocks. The structures he takes to be vesicular, amygdaloidal, bombs, pebbles, and the like, are to my eyes only concretionary forms, and forms produced in the process of extensive leaching and weathering, and the same series followed underground in depth in drill cores shows no traces of the diabasic feldspar structure, though it seems to me much fresher. Winchell, however, supposes the whole series as found to have been exposed to atmospheric agencies, a sort of series of laterites and palagonites. But even in the thoroughly kaolinized dikes of the Gogebic range, I find no difficulty in seeing a diabasic texture. On the other hand the structure of the fresher material of the iron bearing series is always largely cherty, that of precipitated silica.

10. Van Hise† considers that the iron was transported as carbonate and sulphate, precipitated by oxidation and hydration as limonite and basic ferric sulphate or as sulphide by organic material—and that later when buried with organic matter it became carbonate, and was later leached to hematite.

11. Even this composite theory does not a together cover the ground. The iron formations have been followed over 2,000 feet underground. In fact, on the Gogebic range the Newport mine, for instance, is looking exceedingly well at that depth.

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*Proc. L. S. M. I., XIII, p. 203.

†Iron Ore Deposits of Lake Superior Regions, 21st Annual Report U. S. G. S., p. 320.

In other cases the drill has brought up material that looks exceedingly fresh and free from any alteration by surface downward working waters, which are composed of hematite and silica already. Again, pebbles of well developed jaspilite are found in Keweenawan and Huronian conglomerates. It hardly seems likely then that jaspilite is altogether after carbonate. We are, therefore, disposed to look with a great deal of interest at a series of experiments Van Hise and Leith have been recently directing at Madison, in which the soluble iron as sulphate is precipitated by sodium carbonate or silicate. In the latter case especially the silicate is precipitated with the iron oxide in a form which Leith says, one can easily imagine to be the original of even banded jaspers. Sodium carbonate will do the same thing as we know, but the chloride and probably other iron salts will behave like the sulphates. Now we know that chlorine and chloride of iron are attendant on many volcanoes and volcanic eruptions, so that we should certainly keep a place for chlorides among the possible salts.

We have simply to imagine then, according to Leith's theory, that the waters leaching the iron from the basic rocks found their way into basins, which also received the waters of rivers containing alkali carbonates or silicates, just such waters as come off the Laurentian highlands in the Ottawa river to-day, as the recent analysis from R. A. Daly, which I cite, shows*.

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*Analysis Ottawa River water after R. A. Daly.

SiO_2	7.06	
Al_2O_3	.52	
Fe_2O_3	.70	
MgO	2.77	
CaO	8.18	
Na_2O	2.14	—.436 Na_2O for Cl=1.70
K_2O	.67	
SO_2	2.51	
Mn_2O_2	.86	
P_2O_5	.43	
Cl	.50	+ .324 Na = .828 NaCl
Sum	26.34	
Loss on ignition (CO_2)	15.74	
Total solids	46.07	

It is notable that over and above the alkali chloride there is a good amount of alkali carbonate or silicate.

We do not have to assume that, if the atmosphere at the time was oxygenated, the iron was thrown down as bog iron as at present or if it was reducing, that it was thrown down as carbonate. In any case iron oxide and silicate may have been precipitated, alkali chloride remained, thus:—

$Fe_2Cl_6 + 3\,Na_2Si_4O_9 = 6\,NaCl + Fe_2O_3 + 12\,SiO_2$ or $Fe_2Cl_2 + Na_2Si_4O_9 + 2O = 2NaCl + Fe_2O_3 + 4SiO_2$. I think there is reason to believe that this is a very important reaction to consider.

12. While precipitation may have been thus purely chemical, according to Leith's suggestion above outlined, yet, just as Chara throws out lime, and our bog lime deposits are largely organic, not directly chemical, so analogous organic forms may have furnished oxygen for oxidation even as Crenothrix at the present day, even though the air was not oxygenated.

With all these possibilities of primary formation of the iron oxides as well as of secondary leaching from the present surface, it becomes interesting to see if we can get any trace of the original waters in which the iron oxides were laid down. The bearing of such researches on the course and persistence of the chutes of ore is obvious. They will help us perhaps to decide which of the several theories are the more applicable to a particular case. See also my paper* on Mine Waters.

And I may also suggest that if one will keep track of the character of the water from different parts of the mine, it will *often be possible* to get *much better boiler water* by using only the water of certain levels. I present accordingly some analyses. Many of them are included in a recent paper to the Lake Superior Mining Institute.† But I have corrected some misprints and the analyses from the Harmony Iron Company's Germania mine at Hurley, Wisconsin, are new and I have to thank Dr. A. A. Koch for them.

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*Bull Geol. Surv. Vol. 19 (1909) pp. 501-511.

†Volume XIII, 1908, pp. 63–74.

MICHIGAN IRON COUNTRY MINE WATERS.

	Vulcan			Ishpeming	Ironwood	Hurley	Bessemer	Champion.	Republic
	1	2	3	4	5	6	8	10	12
Total Solids (sol.)	.340	.344		.232	.142	1.493	.309	7.10	45.59
Organic	.052			[.020]			.055		
Carbonate *ion* CO_3	.051	.163	.171	.046	.070	[.037]	[.050]	low	
Non volatile or solids after ignition	.250				.0876	1.007			
Chlorine Cl.	.061	.019	.0085	.034	.016	.638	.060	3.061	25.36
Calcium Ca.	.060	.062	.062	.022	.025	.220	.040	.817	7.902
Sodium Na.	.000	.006	.011	[.047]	.003	.081	[.039]		7.29
Magnesium Mg.	.038	.028	.030	.005	.009	.073	.008		.567
Potassium K.	tr.	.013	.004	with Na.		tr.			
Silica SiO_2	.006	.010	.011	.010	.012	.010			
Alumina Al_3O_3	.004	.018	.002	.001	.001	.020	.003	p.n.d.	.700
Iron Oxide Fe_2O_3	tr.							0	tr.
Sulphate ion SO_4	.043	.013	.011	.040	.005	.058	.040	.37	1.045
Sum	.212	.332	.311	.205	.141	1.137			42.157
Ratio Ca: Cl	.99	3.2	8.9	.65	1.56	.345	.66	.27	.31
Na: Cl	0	.315	1.8	1.38	.187	.127	.65		.284
SO_4:Cl	.70	.68	[1.47]	1.18	0.31	0.092	0.66	0.12	.041

Stated in grams per liter, ounces per cubic foot.

1. Vulcan mine mainly from flow of water in the pump station on 15th level "coming from the talcose or sericitic slates," altered eo-Huronion dolomite "underlying the north ore formation." Analyst E. E. Ware. While neither potassium nor sodium were determined quantitatively, it was because there was too little, and the analyst especially reports that the potassium is high relatively to the sodium which is "very small." This is also shown in analysis 2. See annual report of the Board of Geological Survey of Michigan for 1903, p. 156, and Proc. L. S. M. I., Volume XIII, p. 65–68.

If this were a magmatic water from granite as the excess of potassium relative to sodium suggests, one would expect lithia. But there was no lithia or strontia. Judging from other analyses, downward leaching surface water should have more sodium. The sodium as a matter of fact rose as pumping was continued. The easiest hypothesis is that it is (an originally buried) a connate water.

2. Vulcan mine water after the especial flow had dropped off and the total pumping from 2807 to 1000 gallons per minute of which 280 came from another flow, analysis 3 coming from the slates above. Analyst G. Fernekes.

3. From Vulcan mine from 15th level from slates overlying the ore formation, chlorine calculated. It is worth noting, with regard to the potash, that in 11 out of 15 samples of the ore potash was returned, sodium in but 5.

It is perfectly clear on studying these analyses that the water that caused the great flood had just about as much calcium as the other water drained by the mine, but that the calcium instead of being combined with CO_2, was combined with chlorine and sulphate iron, that the sodium was much less. The ore of this mine is more calcareous than some and it occurs at times cemented together with poikilitic patches of calcite.

4. Ishpeming. Collected by A. Formis at a depth of 825 feet. The absence of the dolomite formation is plainly apparent. The chlorine is more than a superficial amount but there is ample sodium to satisfy it. This is not at so great a depth as the Vulcan mines and the circulation of sodium silicate and carbonate downward has presumably been more thorough. The hole went 350 ft. into lean ore 35% and jasper, without reaching the diorite foot wall.

5. Aurora mine. Taken by myself with Mr. E. A. Separk, chief chemist, 200 feet west from A shaft, about 900 feet down at a point which had been opened some five months, Oct. 19, 1908. Temperature 61° F. Dip of shaft 60°. This is water coming down along the top of a kaolinized dike, and No. 6 is from a similarly located vugg. This is only one-tenth as strong as water in the Germania mine, only 10,000 feet away at the same level, No. 6. Does this indicate a more active circulation at the Aurora?

While this is about one-tenth as strong as 6, and the calcium and magnesium and sulphate iron are less in similar proportions, the silica is about the same throughout analyses 1–6. This may be due to chemical equilibrium with the surrounding silicious rocks.

The chlorine is only one-fortieth as strong, and the sodium one twenty-seventh. The sodium is so low in fact that we cannot imagine any dilution of a water like 6 with any surface water, of which we now know, that would give a water like No. 5. If on the other hand one imagines 6 produced from 5 by an absorption of water and certain other constituents, then we see that the chlorine must have been least absorbed, the sodium next, the calcium, magnesium, and sulphate about equally.

6. Harmony Iron Co., from vugg on 9th level of Germania mine, Hurley, through Prof. H. L. Smyth and Capt. King. Analyses through the kindness of Dr. A. A. Koch, Houghton, College of Mines. This cave or enormous vugg was found on the 14th level about 700 ft. east of the shaft on the foot wall quartzite. Smyth reports it undoubtedly a solution cavity, about 200 ft. long, 60 ft. or more in maximum width and perhaps 90 ft. high.

There was also an analysis made of water from the bottom of the shaft. This dike is of the usual type, the intersection with the plane of the lode inclines to the east and so do the ore chutes. The strike is somewhere off toward the Porcupine Mountains.

7. A sample from the bottom of the shaft yielded 3.793 per thousand chlorine, 1.426 calcium (Ca : Cl = 0.377) and only 6.000 solids after ignition. It must have spattered or lost Cl as this would imply 3.96 $CaCl_2$ + 2.08 NaCl = 6.040 solids, to say nothing of other constituents.

8. Yale mine near Bessemer, a boiler test of the general mine water. Beside this boiler water test through Wickes Bros., there are a large number of tests of chlorine made for us by Geo. H. Abeel, Jr., E. B. Smith and Dr. A. A. Koch*. It appears that down to the 9th or 10th level (863 feet vertical) at which point was a flat dike, there was no trouble with the water. The chlorine in the Yale at the 9th level was 40 per million. Down to the 15th level (1,200 feet vertical) the water as pumped has 225 per million Cl.

9. The water between the 10th and 20th levels had 1,070 per million of chlorine and 429 of Ca, about six-tenths as strong as 6, with a similar proportion of Ca to chlorine (.4).

On the 10th level at various points, Mr. Geo. H. Abeel, Jr., found from 70 to 350 parts of chlorine, the latter being a good way from the lode. There was no notable difference above and below the dikes. On the 17th level to the west his tests gave 420 and 490 parts per million respectively; on the 19th level his tests gave 840 (twice as much), and on the 20th level to the east a test gave 1,330 of chlorine. In the Newport mine, clear down at the 15th-17th level the chlorine is but 70-140 per million.

No. 9 is a partial analysis by Dr. A. A. Koch.

10. Sample of water from Champion iron mine, through W. H. Johnston, 28th level, 800 feet east of No. 5 shaft. See Proc. L. S. M. I., p. 73. Analyzed by M. A. Cobb. .71 to .72%. "Much less CO^2 than in Lansing city water" (*i.e.*, less than .200 of CO^3).

12. Republic iron mine, 1,710 feet down. Proc. L. S. M. I., XIII, p. 72. With a trace of manganese.

There is one other analysis which should also be considered since it comes from Huronian rocks, and that is the Silver Islet water.† It is only 500 feet deep but has nearly 40 per million solids and Ca : Cl_2 = .363.

There is yet much to be learned, but there are some things which are already apparent.

1. We do not have to go far from the surface to obtain chlorine that is not associated with sodium, which we may call calcium chloride. This can not be due to surface or accidental organic contamination.

2. This calcium chloride occurs not only in the iron mines but in the copper mines and the older paleozoics, and has been attrib-

*Proc. L. S. M. I., XIII, p. 71.

†Canada Geological Report H. 1887, pp. 28, 58. Proc. L.S.M.I., p. 74.

uted by T. Sterry Hunt and others, as well as myself, to the early sea water. There is no positive proof that in some cases and to some extent it is not due to volcanic emanations or leached from silico-chlorides and the like.

3. At considerable depths the waters of the iron mines are rather fresher than those of the copper mines. This *may* be due to greater absorption of water in the hydration of the melaphyres of the Keweenawan rocks.

4. But the waters of the iron mines contain proportionally much more of sulphates than the waters of the copper country.

5. The dikes are known to guide the circulation of the water and the ore chutes on the Gogebic range. But a series of tests for me by Mr. Geo. H. Abeel, Jr., seem to show that there is no material difference in chlorine just above and just below these dikes. This may be explained by saying that the circulation all happened so long ago that relatively active irons like those of chlorine to have diffused around so as to even up all minor local differences. There is, however, at times a most remarkable difference in the distribution of phosphorus above and below the dikes, as ore analyses show.

6. The silica is no greater in the deeper waters than in the shallower. It is about 10 parts per million and that is about all an ordinary cold water can take.

There is therefore no support whatever to my suggestion of 1893, of the upward working alkaline silicate waters. Because in such case we would expect to find the deeper waters saturated or supersaturated with silica.

7. The carbonate radical is low and even less with depth. There is no indication of any such reaction as:—

$$2\,FeCO_3 + O = Fe_2O_3 + 2\,CO_2.$$

None of the waters are saturated with bicarbonates, as one might expect if any such reaction had been going on to any great extent. And if one would say that that took place so long ago that all trace of the reaction has been removed, one is led to inquire how that could be done without also removing the chlorine.

It is worth noting, too, that springs of soda water, such as the Saratoga springs, are unknown in the iron region.

While, therefore, the theory of the transfer of the iron as carbonate and bicarbonate is altogether the natural and probably the proper one for Irving and Van Hise to have assumed antecedent to the accumulation of the facts now presented, I feel now forced to abandon it, and to look to the chloride and to some extent the sulphate as the form in which *transportation* took place. If the agent of precipitation contained sodium carbonate, we should have the iron carbonate formed which has led to the former hypothesis; if sodium silicate, we should have silica and iron. Calcium might perhaps in certain cases replace the sodium in the precipitating agent to some extent, but calcium chloride is much too wide spread in the early waters to suppose for an instant that the calcium chloride in these mine waters is due to such a reaction.

It would seem to me that Leith and Spurr are very nearly right, that the early concentration of the iron ore probably took place in the Huronian seas, which were a solution mainly of chlorides with neither calcium nor sodium over four-tenths the amount of chlorine. In fact, if we may trust the Vulcan No.1 analysis, there was very little sodium indeed.

Into such waters the chemical decay of rocks introduced sodium silicate and carbonate, which threw down the iron as oxide or carbonate with silica.

The sulphates were of minor importance.

The later concentration, relative to the present troughs and more or less present surface may have been due to very soft, slightly alkaline waters, pluvial waters, from the Laurentian granites perhaps, which have worked mainly by removing the silica. Possibly heat from Keweenawan igneous rocks and from the earth's interior may have aided in the solution of the silica and in their circulation.

Though these waters have persistently more sulphates than those of the copper mines of equal concentration, I do not know the full meaning of this fact. Barite occurs at times in some of the iron mines.

Another thing that must remain for a while fit subject for debate is whether the stronger waters have not been concentrated by absorption of some of the water in hydration, or how otherwise they obtained their strength, which is greater than that of the present ocean. For various reasons it is not likely that the early ocean was more concentrated than the present.

THE CONCENTRATION OF LOW GRADE MAGNETIC IRON ORES.

By G. C. MACKENZIE, Kingston, Ont.

In November, 1907, the writer received instructions from Mr. T. W. Gibson, Deputy Minister of Mines for Ontario, to make a report on "The Iron and Steel Industry of the Province," with special reference to the problem of concentrating and preparing for blast furnace use the low grade magnetites of the eastern and northern townships. In this connection, it was deemed advisable to visit several of the larger American magnetic concentrating mills, where the process has been in operation for some years, and at the same time, whenever possible, to witness the operation of American blast furnaces burdened with these concentrated ores.

Accordingly visits were made to the mills at Mineville, N.Y., operated by the Witherbee Sherman Co., and to the Cedar Point furnace at Port Henry, N.Y., where Mineville concentrates are almost exclusively used; to the separating plant at Lyon Mountain, N.Y., operated by the Delaware & Hudson Railroad, and to the Standish, N.Y., furnace, which takes a large portion of the output of Lyon Mountain Mill; and finally to the plant of The Pennsylvania Steel Co., at Lebanon, Pa., where the low grade Cornwall ores are concentrated, and subsequently nodulized before being smelted. Description of these plants will be found in the seventeenth (1908) report of the Ontario Bureau of Mines, the descriptions being accompanied by cuts of the various mills, descriptive data, chemical analyses, etc., illustrating the results obtained.

The problem of concentrating low grade Canadian magnetites, by means of magnetic separating machines, has been discussed from time to time in various papers read before the Institute. These papers contain much valuable information on the subject, giving detailed descriptions of many different types of separators used on this continent and abroad. In the present instance, no

attempt will be made to describe any particular process or separator, but rather to present, in general, some of the more important features of the problem under consideration.

The basis of all magnetic concentration is the fact that different mineral species possess different ratios of permeability. The more permeable a mineral is, the stronger the tractive force exerted upon it by the electro magnet, and *vice versa*. Exhaustive experiments to determine the relative permeability of different minerals have been carried out by Walter Crane. His methods of determination, with full tabulated results are given in the Transactions American Institute of Mining Engineers, Vol. XXXI, page 405. The following list of the more common minerals is taken from Mr. Crane's monograph.

Relative Magnetic Permeability of some Common Minerals.

MINERAL.	PERMEABILITY.
Iron	2.1617
Steel	2.1532
Magnetite	1.4669
Franklinite	1.4112
Ilmenite	1.2871
Pyrrhotite	1.0782
Hematite	1.0242
Siderite	1.0234
Limonite	1.0099
Pyrite	1.0064
Quartz	1.0055
Talc	1.0039
Apatite	1.0026
Calcite	1.0040
Barite	1.0000

It is evident from the foregoing table that magnetite may be easily separated from quartz, pyrite, or apatite, from pyrrhotite not so easily, and from ilmenite with difficulty. However, this fact is well understood by designers of magnetic separators, and there are to-day several different types of machines on the market that will make a separation of minerals, possessing but slight differences in permeability.

The main object in concentrating low grade magnetic iron ores is, of course, to increase the iron content as much as possible, and at the same time to get rid of any harmful substances, such as sulphur or phosphorus, that exist in the crude ore to an obnoxious degree. Ordinary gangue material such as quartz, calcite, or feldspar, are easily eliminated, so also are pyrite, and apatite; but if the sulphur exists in the form of pyrrhotite, its removal is not so easily accomplished, and if phosphorus is found in chemical combination with the iron as phosphate or phosphide, it cannot be separated by the electro magnet. Titanium can be eliminated only when that element is present in the form of titanite. If it exists as ilmenite, there is no chance of its successful separation from magnetite on a commercial basis.

There is, however, another feature of this problem which is of equal importance to the chemical composition of the ore, and that is its crystalline structure. Ores that are coarsely crystalline are easily disintegrated by crushing, the constituent minerals falling apart without forming any excessive amount of dust particles, so that when subjected to the separation process the heads product is not only clean but is coarse enough for direct use in the blast furnace. Magnetites of this class are being concentrated at Mineville, the concentrated product averaging 65 per cent. larger than ten mesh. On the other hand ores of finer crystallization require more pulverizing to effect a complete disintegration of the constituent minerals, and the crushed material containing considerable dust is concentrated with more difficulty, yielding a heads product that is in general too finely divided for blast furnace use. Magnetites of the latter class are being treated at Lyon Mountain, N.Y., the concentrates in this case averaging 8 per cent. larger than 10 mesh, 50 per cent. between 10 and 40 mesh, with 42 per cent. smaller than 40 mesh. The use of these concentrates at the Standish furnace gave considerable trouble. until a nodulizing plant was installed for the purpose of agglutinizing the fine material.

Both the Mineville and Lyon Mountain mills are operated dry. The crude ore after being crushed to small size is heated in vertical driers to expel moisture. This preliminary drying, although expensive, is necessary for efficient dry separation, because individual particles must be free to be attracted or

rejected by the magnets, and moisture would seriously interfere with this freedom of movement. The mills are equipped with heavy and costly crushing, sizing and conveying machinery for economical handling of the crude ore, of which some thousand and odd tons are handled every twenty-four hours.

Ores of extremely fine crystallization, containing pyrites or other objectionable gangue minerals finely disseminated, require excessive pulverization to liberate the particles of pure magnetite. Such pulverized material is difficult to concentrate dry on account of the amount of dust, fine particles of gangue being carried into the heads entrained with particles of magnetite. This difficulty is overcome by mixing the material with an excess of water and allowing it to flow underneath the poles of a strong electro magnet, the particles of magnetite being lifted out of the wet pulp without entraining any undue proportion of gangue particles.

The process of wet separation is in operation at the Lebanon plant of The Pennsylvania Steel Co., the concentrates obtained being in a fine state of subdivision are partially dewaterized and then nodulized in long tubular kilns using powdered coal for fuel.

There are, then, two distinct systems of magnetic separation. First, the dry process, which may be applied to ores of fairly coarse crystalline structure requiring the crude ore to be thoroughly dried before it can be handled by the separating machines. In following this method of concentration it is usual to carry the preliminary crushing just far enough to free the average sized particles of pure magnetite. The crushed ore is then sent to the separators, making a three part separation; concentrates that require no further treatment; tailings depending on their iron content, may be disposed of as waste, and middlings consisting of particles that are half magnetite and half gangue requiring a second crushing and separation. This secondary separation may be followed by a third and possibly a fourth similar operation, until the iron content of the final tails falls below the economical point of recovery. Concentrates produced by this method may or may not require briquetting or nodulizing, depending on the fineness of the material. The wet process is more particularly applicable to ores that require much grinding to free individual particles. No partial crushing is necessary in this case, and as

the process is carried out with the aid of a considerable amount of water, preliminary drying is of course obviated. In practice the ore is reduced to medium size in large rock breakers and is then fed to wet ball mills that discharge the finely disintegrated pulp to the magnetic separators. The separators as a rule make but two products, concentrates and tailings, and are usually so adjusted that the tails are uniformly low in iron, being then discharged to the waste dump. The concentrates obtained may be accepted as a final product, or if a higher iron content is desired, they may be reground in ball mills or tube mills and subjected to secondary concentration. The final concentrates are then partially freed from water, and as they are much too fine for direct use in the blast furnace, they must be either briquetted or nodulized.

The most successful system for *briquetting* and desulphurizing small iron ores is undoubtedly the Swedish Gröndal process described by Mr. P. McN. Bennie, in Vols. X and XI of the Institute Transactions. Mr. Bennie has explained this method so well that it need not be enlarged upon here and those requiring full details are referred to Mr. Bennie's interesting paper.

The nodulizing process is to date the most successful American method of sintering concentrates, flue dust, and small ores generally, forming small nodular masses of the material treated. Briefly described the process consists of feeding the finely divided ore into the upper end of an inclined rotary kiln. The kiln rotating slowly on its longer axis is fired at its lower extremity by blowing in coal dust, generating an extremely high temperature. The fine ore sintered into masses by the heat is tumbled about and broken up into nodules by the rotating movement of the kiln, finally being discharged at the lower end. The Pennsylvania Steel Co. have four of these kilns installed at their Lebanon plant, treating the concentrated magnetite from the separating mill. The concentrates, as fed to the kilns, average 61 per cent. in iron with 1 per cent. of sulphur. The nodules produced contain between 58 and 60 per cent. of iron with only 0.03 per cent. of sulphur, showing that the kilns are efficient desulphurizers, and also that the Fe_3O_4 in the concentrates, is partially oxidized to Fe_2O_3 in the nodules. With all four kilns in operation the plant produces daily about 400 tons of nodules which are quite hard and porous, 80 per cent. of the product being larger than $\frac{1}{4}$ inch and nothing

is finer than 12 mesh. Hence it makes a most desirable material for the blast furnace.

The coal consumption at Lebanon, per gross ton of nodules, will average, it is said, 8 per cent., this being 1 per cent. in excess of the fuel consumption claimed for the Gröndal briquetting furnace. However, the unit capacity of the nodulizing kiln exceeds the unit capacity of the Gröndal furnace, and the cost of installation is much lower in the case of the former.

That magnetic concentrates if *properly prepared* are ideal for use in the blast furnace is freely conceded by practical iron men. The slag forming ingredients are uniformly low and the iron content will vary but slightly from time to time. Any deleterious element such as sulphur or phosphorus that existed in the crude ore being reduced to uniformly low percentages, that will give but little trouble in smelting. These points are keenly appreciated by furnacemen for they mean a greater yield of pig iron per ton of ore, resulting in lower fuel consumption, a more even running furnace, because the chemical and physical conditions of the ore are not subject to extreme variation, and consequently a greater output of pig iron at a lower cost.

During the year 1907, iron blast furnaces in Ontario consumed 508,883 gross tons of ore; of this amount 76.3 per cent. was imported from the United States and 23.6 per cent. was mined within the province. These figures clearly illustrate the present status of iron ore mining in Ontario and convey the impression that our iron ranges are limited in extent. We have one mine, the Helen in Michipicoten, that is worked on a scale approaching modern requirements. The ore being a non-bessemer brown hematite, is for the most part exported to the United States in exchange, as it were, for American bessemer ores which are greatly in demand at Ontario furnaces. A large body of magnetite at Moose Mountain, north of Sudbury, is being exploited and promises to be importantly productive; this ore is, however, also of non-bessemer grade. The Atikokan mine, 130 miles west of Port Arthur, was worked for some time in 1906-1907, the high sulphur magnetite produced being roasted and subsequently smelted in the Atikokan blast furnace at Port Arthur. The furnace going out of blast in December, 1907, has stopped mining operations since that date. In eastern Ontario, the Canada Iron Corporation Ltd. are working

deposits of magnetite at Bessemer, the ore after hand sorting being of bessemer quality. The corporation also control the Eganville deposits, but at present are not working the mine. There are numerous deposits of low grade ores along the Central Ontario and Kingston and Pembroke Railways. On the Central Ontario may be mentioned Coe Hill, Belmont, and Blairton, also several of the ore bodies at Bessemer. Along the Kingston and Pembroke Railway the most conspicuous are the Calabogie, Robertsville, Flower, Wilbur and Glendower deposits. All of these mines have been worked at some time or another, the operators taking out the richer pockets that required little or no sorting, mining being discontinued when any considerable amount of poor ore was encountered. In the northern part of the province are found the banded jaspilyte ores as at Temagami Station. Also the finely crystalline silicious magnetites of the Hutton range. Magnetites of the latter types are found in abundance on the eastern shores of Lake Nipigon; they also occur to some extent around Lake Temagami and in the township of Boston.

It is evident then that while our known supply of rich ore is limited, we have numerous deposits of low grade material that is of little or no value commercially in the crude state, but which might prove a valuable asset if means were employed to concentrate the iron values and to eliminate impurities. Examples have been cited of what the Americans are doing with their low grade ores in New York State and in Pennsylvania. Also Mr. Bennie has given reliable data on the methods that are followed in Sweden in treating ores similar in character to our own. Therefore, it may be permissible to conclude that successful concentration of our Ontario ores can be carried out, if wise selection is made as to the general adaptability of any process to meet local requirements.

Successful concentration does not, however, spell profits in dollars and cents. An ore may present an easy concentrating problem, and the product of the mill find a ready market, but the financial success of the undertaking will be doubtful, unless the cost of the crude ore and its iron contents as magnetite are commensurate with the cost of producing a ton of concentrates from the crude. The following example will make this more intelligible:—Assume a concentrating mill to have a capacity of 1,000

tons of crude ore daily, the running expenses of the plant remaining constant at $300.00 per diem. This mill is treating a certain ore (A) containing 60 per cent. of magnetite (43.45 per cent. iron), that is costing delivered at the mill $1.25 per ton; producing concentrates containing 90 per cent. magnetite (65.178 per cent. iron) with a loss of 4.5 per cent. magnetite (3.26 per cent. iron) in the tailings. The number of crude units required to make one concentrate unit will be theoretically $\frac{90—4.5}{60—4.5}=1.54$, therefore 1,000 tons of crude ore will yield $\frac{1000}{1.54}=649$ tons of concentrates. The cost of these concentrates for milling is $\frac{\$300.00}{649}=46.2$ cents per ton, to which must be added $1.25 x 1.54 = $1.92.5, the cost of the crude ore necessary to make one ton of concentrates, making a final cost of $2.38.7 per ton of product.

A second ore (B) costing the same ($1.25) per ton delivered, contains only 40 per cent. of magnetite (28.97 per cent. iron). This ore is concentrated with the same efficiency as the first, making a concentrate containing 90 per cent. of magnetite, and with a loss of 4.5 per cent. of magnetite in the tails. In this case $\frac{90—4.5}{40—4.5}=2.4$ units of crude ore required per unit of concentrate, therefore 1,000 tons of crude ore will yield only 416 tons of concentrates, at a milling cost of $\frac{\$300.00}{416}=72.1$ cents per ton; adding to this the cost of crude ore, $1.25 x 2.4 = $3.00 per ton, the final cost of producing concentrates from ore (B) will be $3.72.1 per ton of product. Hence it is apparent that if the final costs of the concentrates produced from ore (A) is allowing a reasonable profit, the price paid for ore (B) should be reduced from $1.25 to $\frac{2.38—72.1}{2.4}=69.4$ cents a ton to admit of making an equal profit in the second case.

There are of course other factors that will influence the final cost of concentrates, as for instance, the rate at which a given ore may be crushed and passed through the separators. But the predominating conditions for success or failure will always be

governed by the cost of the crude ore, and its iron content as *magnetite.*

During the spring of 1908 a few preliminary tests on magnetic concentration of Ontario ores were carried out by the writer for the Bureau of Mines, and the results obtained, although not conclusive, were encouraging. Descriptions of these tests will be found in the seventeenth report before mentioned. At the present time the writer is conducting separation tests for the Bureau on a larger scale at the Kingston School of Mines, three ton samples of low grade magnetites having been secured from five different localities, making a fair representation of the different types of low grade ores met with in Ontario. These ores are being tested for separation efficiency by both dry and wet methods of concentration, and it is hoped that the results will prove of interest and possibly of some value to the iron industry of the province.

THE SINKING OF THE WABANA SUBMARINE SLOPES.

By R. E. and A. R. Chambers.

In June, 1893, the first landing on Bell Island was made by one of the writers in company with the Messrs. Butlers, of Topsail, Nfld., who then owned the property, for the purpose of examining the iron ore beds here.

It could be seen at a glance that the property was a valuable one; but fifteen years of continuous working have brought about striking changes. At the time of this first visit the north side of the island was heavily timbered with fir trees, and to find one's way it was necessary to make use of a compass; the south side was dotted at intervals by primitive farms. Now, however, the quiet peace of the silent forest has given place to the noise and bustle incidental to the operation of a great industry; while the nearly untenanted wilderness has become a populated centre of activity.

Such is the change wrought by the mining of the ore upon the island. But this development is not confined to Bell Island alone. Sydney, then little more than a village, has been transformed into a bustling cosmopolitan city, in whose vicinity is established the most important steel plant in Canada. Across the harbour at Sydney Mines is a group of large furnaces and machine shops served by a network of many miles of track.

The ore deposits and plant on the land at Wabana, have been fully described in previous papers*; hence a further reference here is unnecessary. Recent developments however, carried on under the direction of the writers, in connection with the submarine areas, have proven to have an important bearing on the size of this ore field, and promise still further changes.

It has been shown that the ore upon the land is but a fringe of the greater deposits beneath the sea. The fact of a tonnage

* A Newfoundland Iron Deposit: Chambers, R. E., Jour. Fed. C. M. I., Vol. 1, p. 41, 1896.

equalling the entire requirements of the Scotia furnaces having been steadily mined from the submarine areas during the last six months is good proof of the practicability of working the ore; and in view of the importance of these results, a short account of the developments may not be uninteresting.

HISTORICAL.

At the time of the organization of the Dominion Iron & Steel Co. a sale was made by the Nova Scotia Steel & Coal Co. to them of the bed of ore upon the land then being worked by the latter, known as the lower bed, reserving for themselves the upper bed on account of its superior quality. This sale included a submarine area of three square miles adjoining the shore. Subsequently the Scotia interests acquired outlying submarine areas, which from the great depth of cover would, it was thought, be quite workable over a large area, and on account of the known persistence of the beds in this district these submarine areas would probably contain all the beds known to exist on the land.

Upon the submarine areas each company owns all the beds upon the respective claims, whereas on the land, the lower bed is owned by one company, and the upper bed by the other.

As the work progressed additional areas were secured, and hence at the present time there are thirty-two square miles of submarine areas owned by the Scotia Company, and five and a half by the Dominion.

An agreement was made by which slopes could be driven by the Scotia Company through the submarine areas of the Dominion Company. The point selected was the continuation of the No. 2 slope already being worked on the upper bed. At the shore line here there was cover of 68 feet which was greater than at any other point east or west. The dip of the vein being 8 degrees to the north, or direction in which the work progresses, made it possible to commence the work with the plant then installed until the practicability of the enterprise should be determined. It was known that at distances of about 250 and 1,000 feet respectively, serious faults would be encountered, and it was not considered advisable to make any expenditure for plant until these should have been passed.

Work was commenced on May 21st, 1906. In August the first fault was encountered. Fortunately, although this dislocation amounted to an upthrow of 29 feet with only 85 feet of strata intervening between the workings and the bottom of the ocean, the volume of water encountered was trifling.

From a study of the rock structure upon the land it was fairly evident that this upthrow would be followed by a corresponding downthrow, after driving about 800 feet, running N.E. & S.W., approximately at right angles to the fault first encountered. It was consequently decided to continue the slope in the strata underlying the ore in order to maintain as uniform a grade as possible. The wisdom of this course was verified by encountering the ore beyond the second fault at the distance and height expected, and of greater thickness. This fault was more serious, containing 4 feet of clayey decomposed rock, and an increased flow of water. The soft ground was handled by careful piling and the water could easily be handled by two No. 6 Cameron pumps, the quantity not exceeding 50 gallons per minute.

Beyond this second fault no serious difficulties were encountered for a further distance of 1,800 feet, at which point a downthrow fault of 26 feet was reached. The cover had increased to a total of 293 feet and in consequence a greater feeling of security was felt in providing against any difficulties which might occur. With the increased depth, however, a corresponding increase in firmness was found and the clay encountered in previous faults was not met here. The slope was continued in the strata overlying the ore, but with an increased grade for a distance of 400 feet, when ore was again entered having a normal thickness, and a normal dip of 12 per cent. The grade for the 400 feet was made 20 per cent. which by trimming will be subsequently reduced to 18 per cent. For this 400 feet the effects of the fault were noticed in the increased tenderness of the roof, necessitating timbers being placed skin to skin; and in the amount of water dripping from above. The total quantity of water was, however, in no way formidable. After re-entering the ore bed beyond this fault no difficulties have been encountered to the date of writing. The bed has the normal dip of about 12 per cent., the ore has a section of 9 feet, and the quality is fully maintained.

On entering the Scotia areas at a distance of nearly 4,000 feet from the shore, the conditions are as favourable as could have been hoped, and more so in that the quantity of water handled is very small compared with what was expected.

The advances are as follows:—

Slope commenced May 21st, 1906.

Distance driven to December			31st,	1906.....	704.6 ft.
"	"	"	30	1907.....	1,916.1 ft.
"	"	"	24	1908.....	3,965.0 ft.

The month of least advance was August, 1907, in passing first fault, or ..... 42.5 ft.
The month of greatest advance was Nov., 1908, or.. 247.81 ft.
In the 4 weeks from the 16th of Nov. to the 14th of Dec. an advance was made of ..... 270.1 ft.
In week ending Dec. 7, 1908, an advance was made of 72.5 ft.
This gives a record of $11\frac{1}{4}$ feet per day for a month.
" " 12 feet 1 inch per day for a week.
The size of excavation for this driving was 13 feet to 15 feet wide by 8 feet high.*

A system of bonus payments for rapid advance greatly helped in attaining above results.

PLANT.

Boilers.—The power used in sinking cannot be considered apart from that employed in the operation of mining plant, since it serves for both purposes.

The boiler plant consists of:—

Five batteries of Sterling water tube boilers of 234 h.p. each.
Sixteen upright tubular boilers of 42 h.p. each.

Air compressors.—One Nordberg duplex compressor, cross compounded air and steam, jet condenser using fresh circulating water, direct connected to low pressure crosshead of the compressor.

Steam cylinders 18 – 32×42
Air cylinders 19 – 32×42

*Since this paper was written an advance of 74′ per week has been made.

Capacity 2,500 cubic feet of free air per minute.

One Walker compressor of same type.

Steam cylinder 22 – 42×48

Air cylinder $23\frac{1}{2}$ – 38×48

Capacity 3,500 cubic feet of free air per minute.

The exhaust steam is conducted to a surface condenser using salt water from the sea for circulating water.

One straight line Norwalk compressor, compound steam, compound air with a jet condenser using fresh water.

Steam cylinder 14 – 22×24

Air cylinder $14\frac{1}{2}$ – 22×24

Capacity 1,200 cubic feet of free air per minute.

The total capacity of air compressing plant is 7,200 feet of free air per minute.

Hoisting engines.—In the early part of the work, the hoisting was done by the engine connected with No. 2 slope, being 14×18 double cylinder, Flory single friction drum. As the work advanced it was necessary to supplement this by the addition of a 10×12 double cylinder drum Lidgerwood hoist, placed at the mouth of a shaft sunk near the shore for this purpose, and by an $8\frac{1}{4}$×10 double cylinder single friction drum operated by compressed air, placed in a cross-cut from the advancing slopes.

Ventilating plant.—This consists of a 4-foot and two 3-foot Sturtevant fans. The 4-foot fan is direct connected to a vertical air driven fan engine, and is located near the upper parts of the slopes, just at the bottom of the present workings of the No. 2 mine, of which the slopes are a continuation. This fan is placed in the air course and is operated exhausting. The two 3-foot fans are placed as described below.

The intention was to sink the slope by double entry. In practice, however, it was found that the tendency was to place chief importance upon the slope furtherest advanced, with the result that it finally exceeded the secondary or ventilating slope by a distance of 2,900 feet. To provide for ventilating this long single slope, recourse was had to spiral rivetted galvanized iron pipe, connected with two Sturtevant blowers, with suitable by-pass connection, so that they could be used either as blowers or exhausters. One of these was placed at the upper end of the pipe

and the other reinforcing it about 1,000 feet further down. The first pipe used was 15 inches inside diameter and was found to be too small to give entirely satisfactory results. Below the lower fan 18 inch pipe was installed, which still continues to give a plentiful supply of air to the face of the slope. As the slope advances, new lengths of pipe are added. On account of the blasting, the pipe cannot be laid nearer than within 150 feet of the face, but no inconvenience whatever is felt in working at the face for this reason.

Drills.—Percussion drills of the Sullivan U. O. type are used.

Pumps.—At the bottom of the old mine and near the top of the submarine slopes is an $18\times8\times24$ duplex Jeansville pump of pot valve anthracite pattern. This pump can be operated by either steam or air. The cylinders are so proportioned that it can be moved to a greater depth where the head will be greater if required. The water is delivered through a 6-inch pipe to a drainage tunnel running to the shore.

After passing the second fault the increased water was handled by two Knowles sinking pumps $12\times6\times13$ and $10\times5\times13$. These delivered the water to the shore direct, or to the lodgement of the Jeansville pump as desired. These were subsequently replaced by a $12\times5\times12$ duplex Jeansville anthracite pattern pump to be later removed to a greater depth. The working face was kept dry by two No. 6 Cameron pumps working alternately, and latterly by a No. 8 Cameron, the water not exceeding 50 gallons per minute.

Dams.—To protect No. 2 mine from possible inundation, sites for mine dams were constructed at a point situated vertically below high water mark. When approaching this point the face was narrowed to 6 feet and then gradually widened again, forming a "V." No reduction was made in the height. The sides, top and bottom were lined with concrete. A small pipe was placed in the roof as an outlet for air when pressure should come on the lower side of the dam, and capacious air and water pipes were built into the floor. Timbers to fill the openings were made of 10×10 pine, tapering to 6×6 and piled at the mouth of the slope in the same position they would occupy in the dam and carefully protected from the weather.

Piping.—The air line is 8 in. diameter as far as the workings in No. 2 mine and to the large Jeansville pump, and 5 inches for the rest of the submarine slope. The water discharging line is 6 inches, being double from the large pump to the surface.

Testing air pipes.—The air pipes of the sinking and working mines are periodically tested as follows: All pipe ends are carefully closed as near to the drills as possible. A pressure guage is connected to the section to be tested. The section is then filled from the mains, and the supply valve closed. The air in the line is then released until the guage reads 50 pounds. The time is taken and the pressure allowed to drop by leakage until it reaches 40 pounds, when the time is taken. The loss in cubic feet of free air will be approximately half the volume of the pipe tested. This divided by the time will give the loss per minute. The amount of pipe in each section not being often changed, this information is readily available. The conditions, with the exception of the time, will be practically constant. The pipe fitter is thus constantly familiar with the condition of his pipes. Corrections for temperature would be necessary for accurate results, but in practice are not needed.

Cars.—The cars used are of steel, of 30 cubic feet capacity holding from 1.7 to 1.8 tons of ore.

Tracks.—The tracks are of 28-pound rails except near the face where an 18-pound rail is temporarily used. The guage is 2 feet.

Protection from runaways.—Every tramming section of the slope is protected by a heavy swinging gate, the posts of which are securely hitched in the floor and roof and heavily braced to the walls. Each gate is operated by a boy.

The face is protected by two ordinary swinging Sampson posts placed from 50 to 100 feet back and moved alternately as the work progresses.

A safety switch is also placed a few hundred feet below the brow of the deckhead.

Telephone system.—Telephones are installed in the slopes connecting through a central office with all parts of the works, the office, and the houses of the manager and underground manager.

Inspection.—There is a daily inspection of cars, ropes, pulleys, and all machinery.

METHOD OF WORKING.

Three eight hour shifts are worked. When the air is cleared of smoke from the last shot, the drillers and loaders proceed to the face. The drillers and their helpers begin to assemble the drills and columns, while the loaders employ themselves in throwing back the ore from the face. The drills, of which there are two on this shift, are then set up four feet from the face, and about twenty inches from the rib or side, and each driller puts in five 12-foot centre cut holes, B-1, 2, 3, 4, 5, and C-1, 2, 3, 4, 5 respectively, completing the round in about six hours. The holes are blown out with compressed air when the shift is completed. After having cleared away the face for the drillers, the loaders, six in number, clear off the track, and run in a trip of three cars; they load up the ore thrown up the slope by the previous blast, which sometimes is as much as 100 feet from the face. When the ore is reduced to a heap behind the drillers, one car only is used, and the loaders relieve each other, car about, three at a time. The loaders generally finish at the same time as the drillers. Forty to fifty tons is an average shift's work.

The blasters then load the holes drilled, with 7 pounds of 50 per cent. Acadia dynamite in each, tamping them securely with paper cartridges of clay prepared for the purpose. After the wires and blasting machinery are tested for strength and circuit the round is fired. If the work has been done correctly the centre cut will be taken out as shown in the sketch, and the ore thrown well up the slope. (See sketch). Owing to the heavy burden on these holes they will be only about half shot out. A little high pressure air is turned on at the face immediately after the blast, and the exhaust fans described above speeded up. In the course of a short while the air at the face is quite clear, and while still a little warm, work can be resumed.

The next shift then begins, loaders clearing face as before.

The regular drillers now set their bars four feet back from the face and as close to the rib as possible, and drill holes A-1, 2, 3, 4, 5, and D-1, 2, 3, 4, 5, 12 feet deep. In addition to these two spare drills are set up in the cut and drill holes E-1, 2, 3, and F-1, 2, 3, and G-1, 2, 3, H- 1, 2, 3 respectively, six feet deep. As the extra drills do not come on the same shift each time, there are two

spare drillers on each shift and when not employed at this work, are employed repairing and advancing ventilating pipes, swinging Sampsons, etc., and on other odd jobs.

The order of blasting is now more elaborate than on the previous shift, and on the care taken in this work greatly depends the advance to be gained.

They first load and fire first holes F-1, 2, 3, and G-1, 2, 3, three pounds to a hole. Next they fire the old bottoms of holes, B-1, 2, 3, 4, 5 and C-1, 2, 3, 4, 5, with 3 to 5 pounds each according to necessity. The third round is E-1, 2, 3, and H-1, 2, 3, five pounds to a hole, and finally A-1, 2, 3, 4, 5 and D-1, 2, 3, 4, 5 are fired, five pounds to a hole. This makes a total of about 200 pounds of 50 per cent. dynamite to an advance of $8\frac{1}{2}$ to 9 feet, according to the success of the work done.

The method of using short bars and setting up the drills on top of the ore heap was at first tried and practised for some considerable time, but it was found that while saving a good deal of time in handling the ore, in the long run it did not pay.

The storage, thawing, and distribution of the explosives for both the mines and the submarine slope is done at a central station, which comprises a small magazine, thawing house, with detached boiler room, and a shed for testing detonators, located at convenient distances apart.

The thawing is affected in a small stone building, brick lined and wood faced inside, with an air space between the brick and stone, and the building is provided with a large entry for the reception and disposal of the explosive. The heating system is the ordinary hot water system as used in dwellings. The radiators are closed in wooden boxes to prevent accidental contact with the explosive.

The various blasting crews, namely, wiremen, thawers, magazine storekeeper and detonator tester, are all under the supervision of an explosive inspector, who constantly inspects all operations connected with the use and disposal of all explosives and who immediately reports to the underground manager any unusual occurrence, and if possible, the cause of the same.

RESULTS.

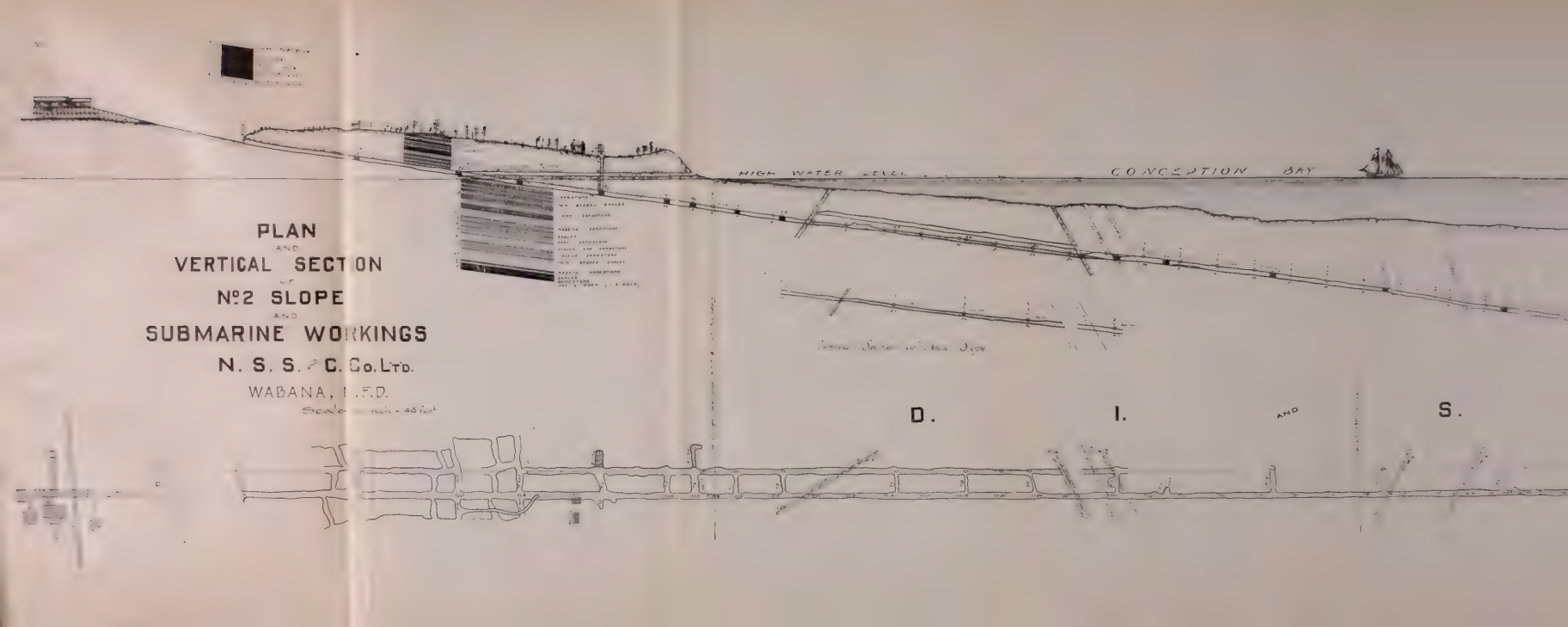
As a result of the work above described it has been proved, as anticipated, that an enormous field of ore, under Conception Bay, multiplies many times the ore previously known.

There have been mined from about 1½ square miles upon the island, about 7,000,000 tons; and there remains yet to be mined about 25,000,000 on this land area.

One of the beds, without deterioration in size or quality, has been followed for three-quarters of a mile under the sea into the areas of the Scotia Company. It is probable that the other beds extend there also.

The properties of this company cover an area of about 33 square miles.

From these facts it will be gathered that the prospects of developing here a practically inexhaustible supply of ore, are extremely favourable.


HIGH WATER LEVEL
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N. S. S. & C. Co. Ltd.
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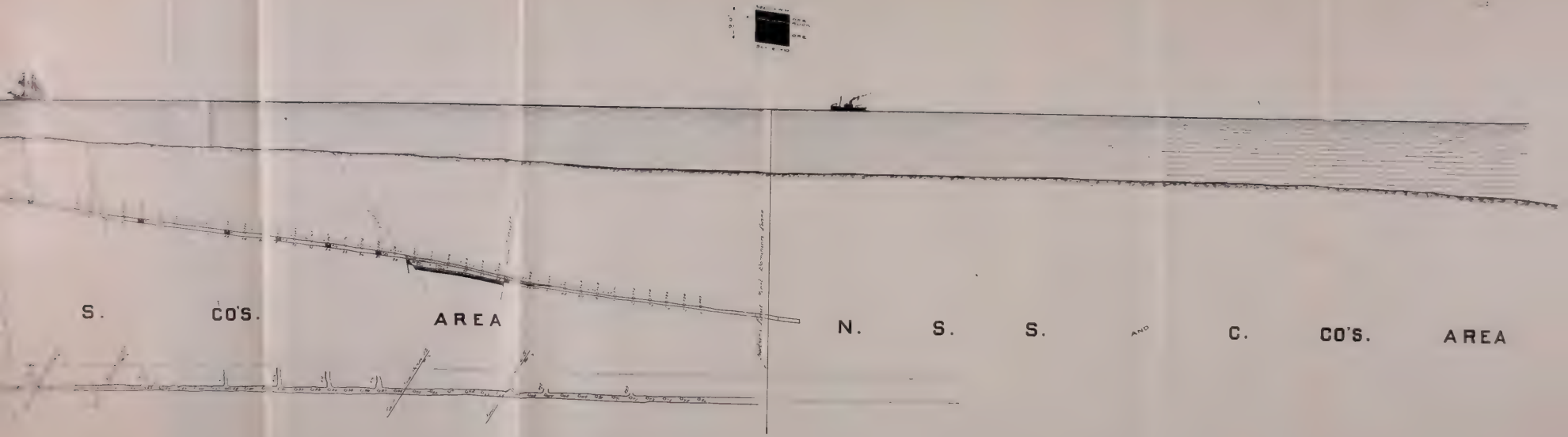
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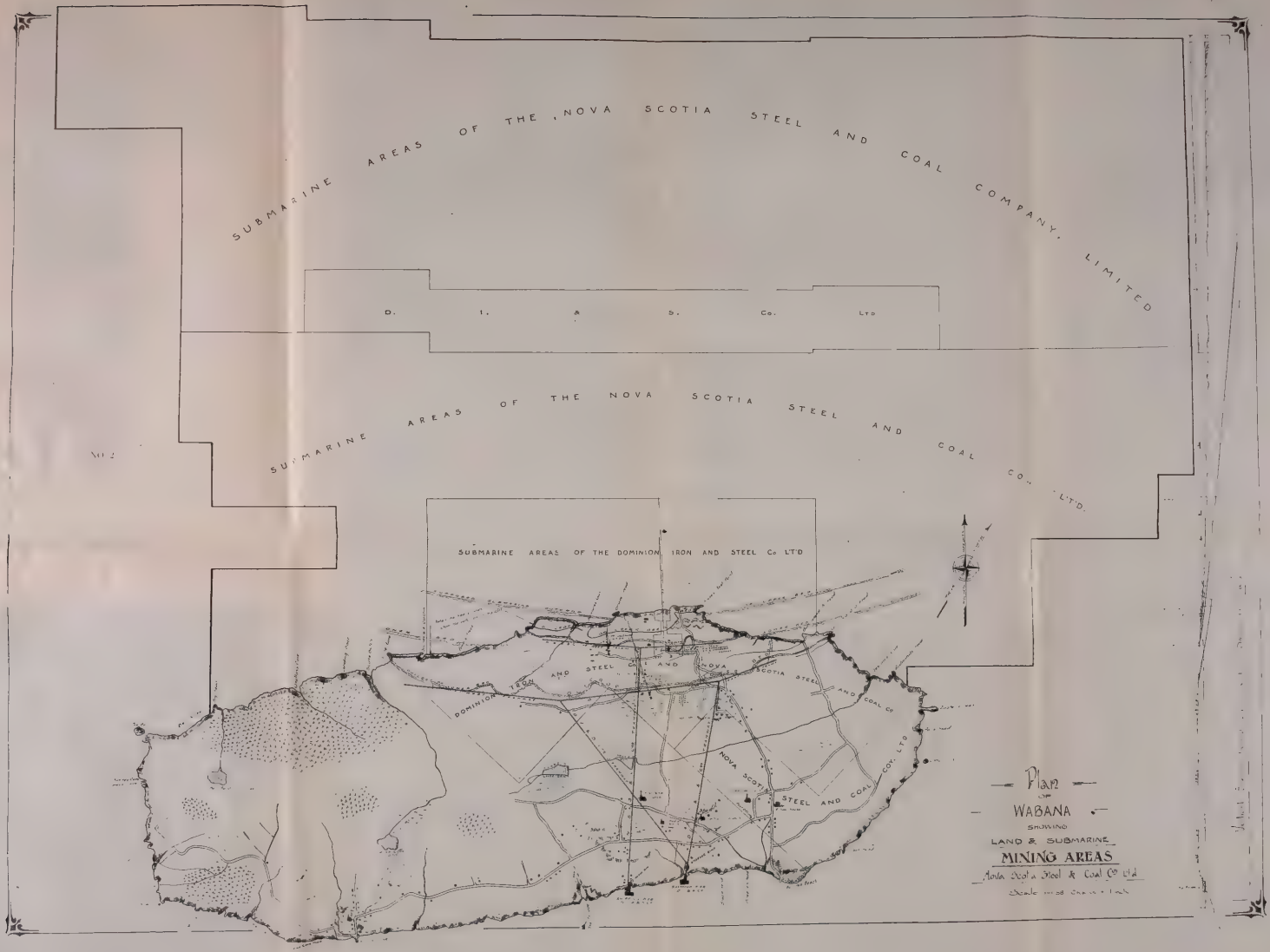
SUBMARINE AREAS OF THE NOVA SCOTIA STEEL AND COAL COMPANY, LIMITED
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Plan
OF
WABANA
SHOWING
LAND & SUBMARINE
MINING AREAS
Nova Scotia Steel & Coal Co Ltd

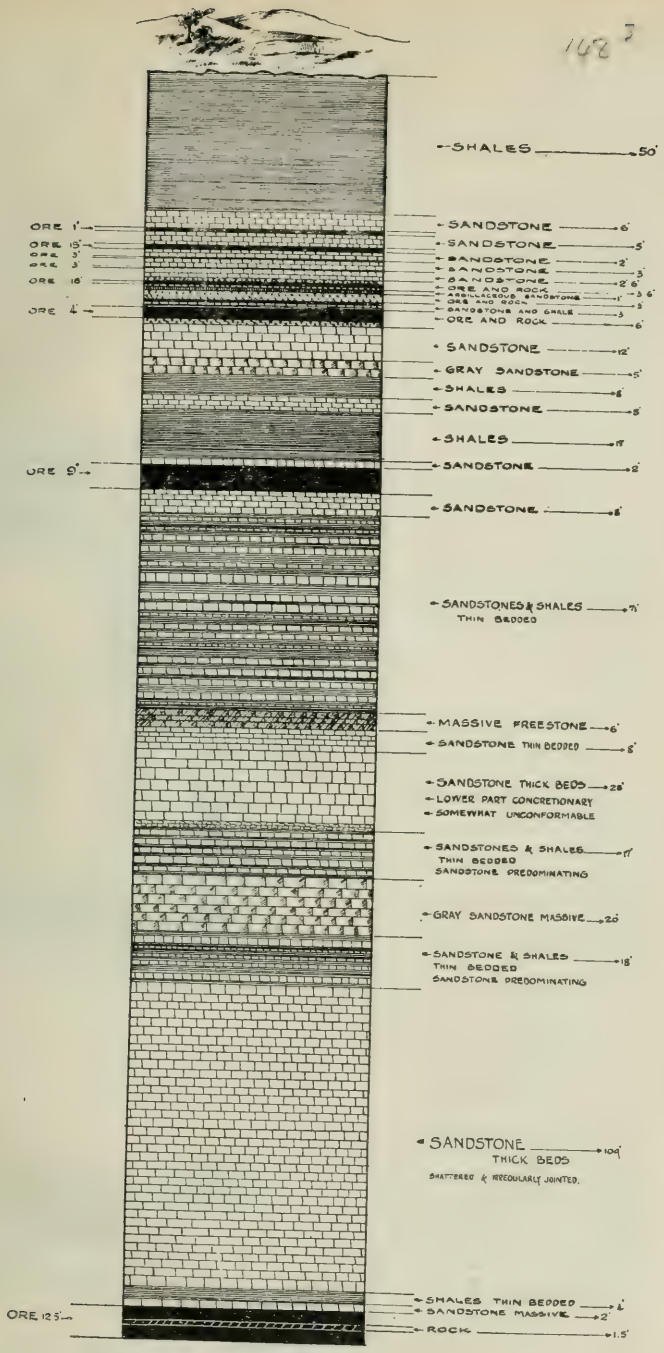
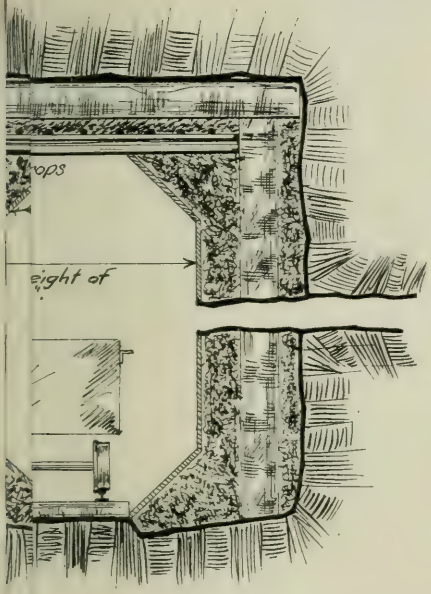

168
SHALES 50'
SANDSTONE 6'
SANDSTONE 5'
SANDSTONE 2'
SANDSTONE 3'
SANDSTONE 2' 6"
ORE AND ROCK 3' 6"
ARGILLACEOUS SANDSTONE 1'
ORE AND ROCK 3'
SANDSTONE AND SHALE 3'
ORE AND ROCK 6'
SANDSTONE 12'
GRAY SANDSTONE 5'
SHALES 5'
SANDSTONE 5'
SHALES 17'
SANDSTONE 2'
SANDSTONE 5'
SANDSTONES & SHALES 71'
THIN BEDDED
MASSIVE FREESTONE 6'
SANDSTONE THIN BEDDED 5'
SANDSTONE THICK BEDS 25'
LOWER PART CONCRETIONARY
SOMEWHAT UNCONFORMABLE
SANDSTONES & SHALES 17'
THIN BEDDED
SANDSTONE PREDOMINATING
GRAY SANDSTONE MASSIVE 20'
SANDSTONE & SHALES 18'
THIN BEDDED
SANDSTONE PREDOMINATING
SANDSTONE 109'
THICK BEDS
SHATTERED & IRREGULARLY JOINTED.
SHALES THIN BEDDED 4'
SANDSTONE MASSIVE 2'
ROCK 1.5'
ORE 1'
ORE 15'
ORE 3'
ORE 3'
ORE 18'
ORE 4'
ORE 9'
ORE 12.5'

Fig. 3



ring & Concreting
in Sinking
Slopes)
½ & ¼ = 4½ Foot.

Nova Scotia Steel & Coal Co Ltd.
Wabana Newfoundland. April 22nd 08.

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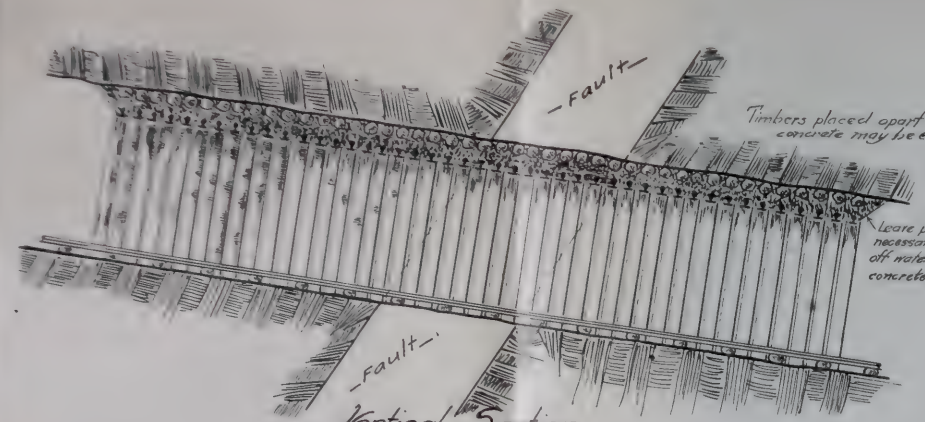
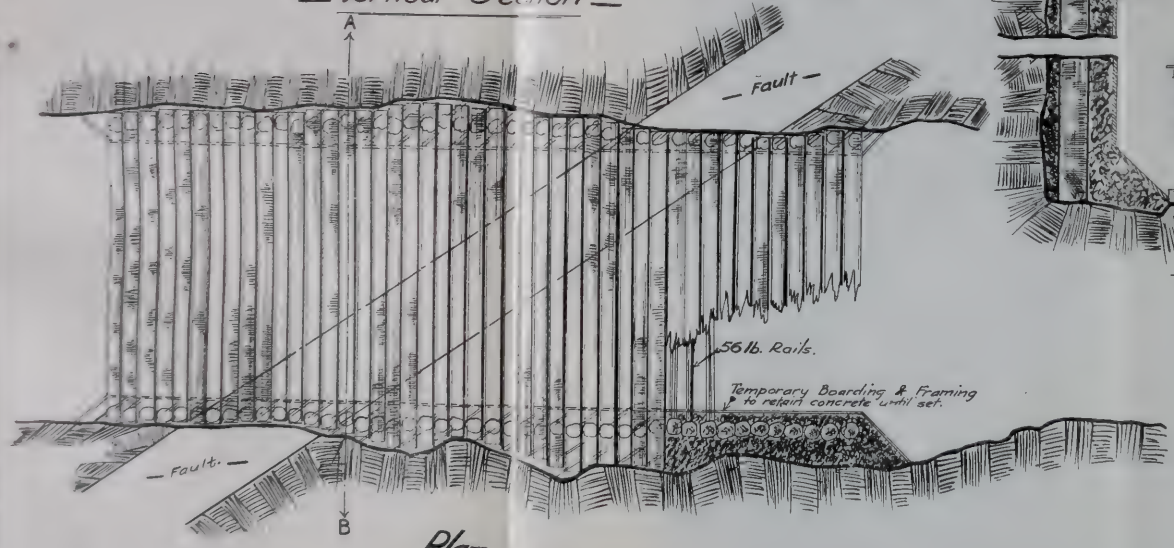
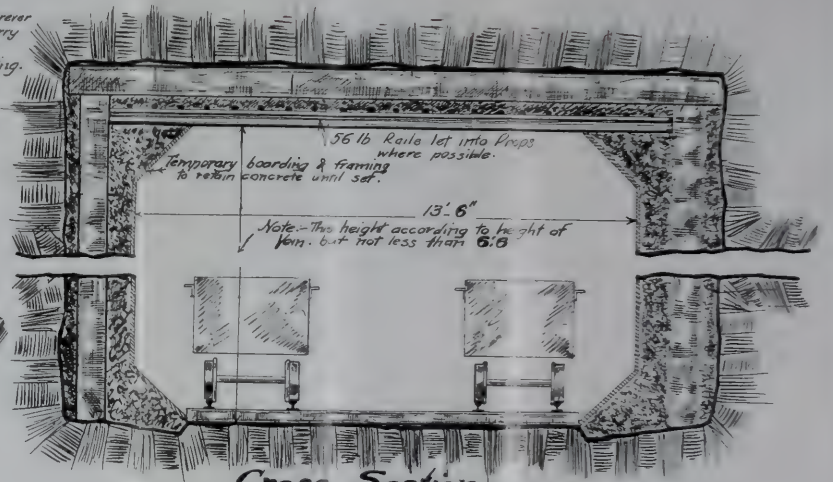

Fault
Fault
Fault
Timbers placed apart so that the concrete may be easily filled around them.
Leave pipe wherever necessary to carry off water while concrete is setting.

Vertical Section



Plan


56 lb Rails let into Props where possible.
Temporary boarding & framing to retain concrete until set.
13'-6"
Note:- The height according to height of Vein. but not less than 6:6

Cross Section thro' A.B.
Scale :- ½" = 4½ ft.

Method of Timbering & Concreting at Breaks in Sinking
(Submarine Slopes)
Scales :- ½ & ¼ = 4½ Feet.

The Nova Scotia Steel & Coal Co Ltd
Wabana Newfoundland. May 22nd 08

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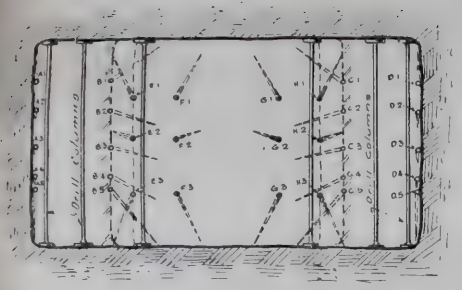
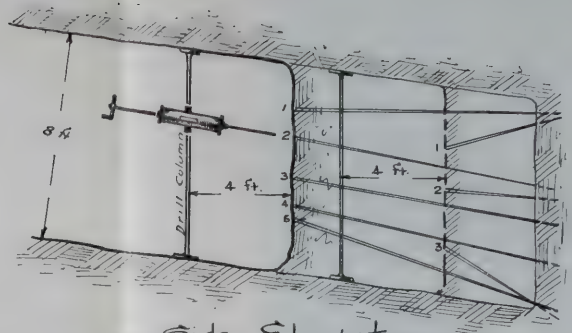
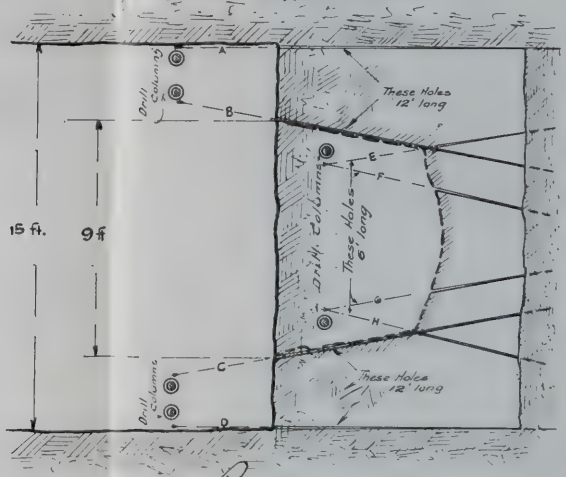


End Elevation



Side Elevation

NO. 5.



Plan

THE MINERAL RESOURCES OF NEWFOUNDLAND.

By James P. Howley, F.G.S.

(Annual Meeting, Montreal, 1909.)

Newfoundland is a country that, during the earlier geological epochs, underwent many vicissitudes. It is underlain by rocks of Laurentian, Huronian, Cambrian, Silurian, Devonian and Carboniferous age.

Large areas are occupied by igneous and igneo-aqueous materials, and highly metamorphosed sediments, indicating prolonged volcanic action at different periods of its structural history. The entire surface of the country is heavily glaciated.

In several respects the geological structure of this island bears a striking resemblance to that of parts of England. On the eastern seaboard the structure of Wales is repeated in the Cambrian deposits. Sediments of almost identical character, holding related fossil organisms, are found on the shores of all the principal Southern and Eastern Bays.

Geographically also, the relation it bears to this continent, is strikingly similar to that which Britain holds to the continent of Europe.

As would be but reasonable to expect in a country composed of the ancient rock formations, abundant mineral wealth exists.

The following particulars of the mining industry to date may prove interesting.

Copper.

Copper mining ranks first in point of time, as it did until recently, in importance. It may be said to have commenced in 1864, when the Union mine at Tilt Cove, in Notre Dame Bay, was

opened. Previous to that date, some desultory mining took place; but during the ten years preceding that time, an output of some 628 tons of ore only is recorded.

The Tilt Cove mine has been a constant producer from its inception until the present date. It was followed in 1875 by the opening of the Bett's Head mine, and in 1878 by that of Little Bay. Several other mines of less importance, all situated in the same great bay, became small producers at later periods. Other sections of the country have more recently attracted attention owing to their promising copper deposits. The Western Copper Company's mine at York Harbor, Bay of Islands, though not as yet vigorously worked, seems destined to become a large producer in the near future. Within the past year a new mine has been opened by some English capitalists at a place called Goose Cove, in Hare Bay, near the northern extremity of the island, and to the end of 1908, some 700 tons of ore had been mined. It is expected by the spring to have at least 1,200 tons ready for shipment.

Altogether, since the inception of the Tilt Cove mine, 1,319,594 tons of ore, 78,015 tons of regulus, and 5,418 tons of ingot copper have been shipped from the mines. The percentages of metallic copper contained in these ores have varied considerably, running from 3½% up to 30%. Estimating it at about 10%, the total yield of metallic copper should be in the vicinity of 140,365½ tons.*

Numerous indications of copper occur all around the coast and on some of the outlying islands, some of which may yet develop into paying properties. Some very rich ores of copper glance, tetrahedrite and erubescite, are found in the older Huronian series in the southern parts of the island. One of these in the immediate vicinity of St. John's City, is just now attracting attention and a local company is being formed to exploit it. The ore is a very beautiful erubescite, running high in copper. Both Conception and Placentia Bays have yielded native or metallic copper in small quantity, and at least one place in the latter bay seems to offer a fair prospect for a paying proposition. The metal occurs on an Island called Oderin, which is made up chiefly of greenstone and amygdaloidal trap, much of which is impregnated with finely disseminated scales or particles of copper. Some portions of the rock are quite rich in metal, and at one point where a break

* The long ton of 2,240 is used throughout.

occurs, many lumps of mass copper were found amongst the debris that had tumbled down from the cliffs.

Until quite recently it was believed that copper deposits, and for that matter, all mineral deposits, were confined to the immediate seaboard, but recent discoveries, by the Anglo-Newfoundland Development Company (Harmsworth), of lead and zinc, on one side of Red Indian Lake, and a large deposit of copper ore on the opposite side, have shown how fallacious this idea was. Red Indian Lake is in the very heart of the interior, and as the country becomes more and more opened up, no doubt other valuable finds will be recorded. No prospecting, worthy of the name, has as yet taken place beyond a few miles from the coast.

Iron.

In a report furnished the Imperial Government in 1895, on the occurrence of iron ores in Newfoundland, it was shown that deposits of this mineral of almost every known variety were found here. These include—magnetite, hematite, limonite, specular and jaspery iron ores, clay ironstone, bog ore, ochreous ores, &c. So far, none of these have been exploited to any extent, except the remarkable deposit of hematite on Great Bell Island in Conception Bay. Nowhere, perhaps, in the world is there to be found a deposit parallelling this one. It is altogether of such an unique character, in its extent, and the interesting geological conditions under which it occurs, that a brief description of its principal features may prove of interest.

Great Bell Island is one of a group of three islands situated in Conception Bay. It is the largest and lays furthest out from the shore, and is about six miles long by an average breadth of about two miles, having a surface area of twelve square miles. It forms, with the other two islands, the remnant of what was once a great trough of Cambrian rocks, which occupied the entire area of the bay. The former existence of this trough is plainly indicated by the presence of narrow fringes of its basic members stretching along the shores of the bay on either side. On the south side, a fringe of about one mile in width extends along shore some ten miles, facing the water and dipping towards it, while on the north side, and about the head of the bay, isolated patches of similar rocks are met with on several of the outer points and

headlands, dipping in the opposite direction; also towards the water. The islands above mentioned form the highest portion of this former trough now visible, but the centre of the trough must still lay out beneath the water some three or four miles north from the Great Bell Island. Numerous typical fossils of the upper Cambrian series are found on the island, and the strata generally are pretty flat, having an inclination of about 8°, pointing towards the North.

The remaining portion of this once extensive trough has been denuded, chiefly by ice action, and the debris carried out to sea. There is ample evidence of this on all sides, the surface of the island itself, and even the ore beds have been worn down, grooved and polished in many places.

Interstratified with the shales and sandstones which compose the structure of the island, there are altogether six bands of ore, ranging from one to eight and ten feet in thickness. Only the two uppermost beds, which are also the thickest, are being mined as yet. One of these averages 6′6″, the other 5′6″ in thickness. They are both situated on the northern side of the island, and occupy the segment of an ellipse, and both terminate on the north shore. So situated are these beds, and so little capping of rock or debris lays over them, that every ton of ore they contain can be recovered. Mr. R. E. Chambers, the capable manager of the Nova Scotia Steel Company's mine, has estimated the total tonnage of the two bands, on the land area, at about 40,000,000 tons. The above named company were the first to operate the mines, commencing work in 1895, when the first cargo of ore was shipped. In 1899 they sold out the lower and larger band to the Dominion Iron & Steel Company, and since then the work of both companies has been vigorously prosecuted. Between them, up to the end of last year, they had shipped 6,848,947 tons. Most of the Dominion Company's ore goes to their large smelting establishment at Sydney, C.B. A large quantity of the Nova Scotia Co's product finds its way to Rotterdam, Philadelphia, and other foreign markets. The pig iron and steel, especially steel rails manufactured at the Sydney works, may be found all over the world. Last summer the writer saw carloads of these rails in transit for the laying down of the great Grand Trunk Pacific road, while quite recently a cargo was sent to India.

In view of the rapid diminution of the Nova Scotia Company's ore, on their land area, that company during the past two years have been driving out under the waters of the bay to reach the submarine areas held by them. These are situated a mile from the shore of the island, the Dominion Company holding the mile immediately contiguous to the shore. Two main parallel drifts, commencing on the land, and following the ore beds seaward, have now reached well within the limits of the company's claim The ore has been found, not only to maintain its regular slope, but to increase both in quality and thickness as the drifts progress.

The writer has gone to some trouble to make an approximate estimate of the probable quantity of ore, the entire trough may yet contain, taking all the six bands into account. By the aid of the dips and strikes of the strata, unless some unforeseen faults or other disturbances occur to throw the ore out, it is possible to get a fair idea of the extent and depth of this trough, and, provided the ore beds continue to maintain their thickness, and regular stratified character throughout, to arrive at a fairly reliable result. According to this mode of figuring then, the trough should contain the enormous quantity of some 2,362,512,640 tons of ore.

The writer will not hazard any opinion as to the amount that may be recoverable; that will largely depend upon the conditions met with, the engineering skill to cope with any difficulties that may present themselves, and the adequacy of the machinery employed to keep the mine dry and fully ventilate it.

Chromite.

This is another mineral substance of which the country is known to possess several large deposits. They are chiefly situated at a distance from the seaboard, and as yet only one attempt to mine the ore has been made, near Port a Port Bay on the west coast. Between the years 1895 and 1899, some 6,000 tons of a high grade ore were raised and sent to market. Since then no further attempts have been made to prosecute the industry. Prospecting for chromite, however, has revealed extensive deposits further inland from the same bay, and again on the head-waters of the Bay d'Est and Gander Rivers. Some of this ore was found on analysis, to contain a small percentage of platinum.

PYRITE.

The ordinary iron pyrites (bisulphuret of iron) is a very abundant mineral, and occurs in association with all the copper ores around Notre Dame Bay. Pyrrhotite and arsenical pyrites are also fairly common ores, the former containing a small percentage of nickel, the latter of gold. Only the first mentioned has ever been mined to any extent, chiefly at a place called Pilley's Island in Notre Dame Bay. There were shipped from this mine, between the years 1883 and 1907, both inclusive, 518,280 tons, all of which went to the New York market for the production of sulphuric acid. The ore ranged high in sulphur, averaging 53%.

NICKEL.

The ores of copper, nickel, cloanthite and nickel pyrites were found in association with the copper ore at Tilt Cove, and at one time a small quantity was extracted and marketed. Some 319 tons were produced between the years 1869 and 1876. A little cobalt was also found with this nickel. Possibly, some of the pyrrhotites before mentioned, may be found to contain paying quantities of nickel. They are very like the Sudbury ores in appearance.

ANTIMONY.

A most promising deposit of stibnite occurs at a place called Morton's Harbor on an island in Notre Dame Bay. Some attempt to mine it took place at one time, several years since, when a few thousand tons were extracted. The ore was a high grade one, but presumably the low price ruling for this material was the chief cause of the company's ceasing to operate the mine. At all events, it has now been lying idle for several years past.

LEAD.

Ores of galena are of frequent occurrence on every side of this island, though but little attention has been paid to them of late. There was a time when some considerable lead mining was carried on at a place called La Manche, near the head of Pla-

centia Bay, which up to 1893 produced 18,762 tons. At two other places in this same bay, Laun and Little Placentia, lead was mined for a short time, and considerable ore produced, but the returns from these latter are not available.

Manganese.

Manganese, of low grade, forms extensive deposits along the south shore of Conception Bay in conjunction with the limestone near the base of the Cambrian fringe. A few attempts have been made to test this deposit, though no regular mining has yet been entered upon. Wad or bog manganese is found in many places but no high grade pyrolusite has been discovered here.

Amongst other ordinary metallic substances known to exist the following may be mentioned:—zinc, cadmium, bismuth, tin, tellurium, rutile, molybdenite, &c. Most of these are merely found in small quantities, or as traces by analyses.

Precious Metals.

Gold is not mined at the present time, *per se*, yet the country affords ample evidence of being auriferous. Nearly all our copper ores contain a small proportion of the metal, and free gold has been found on every side of the island, usually in quartz veins. Some attempts have been made to exploit these, but with little success so far. During the years 1904-5-6 a mine was operated at a place called Mings, north of Cape St. John, and seemed to afford fair promise for a while. The lode was a mixed one, composed of magnetite, slate, quartz and pyrite. The first trial assay of 23 tons yielded 10½ ounces free gold in addition to which the slimes carried a value of $55.00. A shaft was sunk upon this lode to a depth of something over 100 feet, and a drift run along its course another 100 feet.

Assays were made of sample lots of ore taken from various depths, as this work proceeded, which gave as a result an average value of $12.44 per ton. Two gold bricks, one of 11 and one of 37 ounces, were produced, and the prospects began to look very favourable for a time, but from want of capital, or some other cause the mine has since been closed down. Another attempt to mine gold-quartz took place at Sop's Arm in White Bay, and in 1903

about 150 ounces were obtained. A few other instances of unsuccessful attempts to mine gold, in different sections of the country, are known to have taken place, with similar results. Nevertheless, if some of those properties had been carefully and economically handled, they might have developed into paying propositions.

Quartz veins are numerous all over the island, but no systematic prospecting for gold, by persons skilled in that particular profession, has ever taken place.

As already stated, nearly all our copper ores are known to contain a small percentage of gold, and in the case of the ore from Tilt Cove, carrying about 1.5 dwts. to the ton, the gold is recovered during the process of treating the ore at the Cape Copper Company's works, Briton Ferry. No actual statistics of the amount or value are procurable, but it is known that in some years from 3,000 to 5,000 ounces were recovered.

Silver also occurs in combination with both copper and galena ores in many places. Some of the latter are highly argentiferous, that from Little Placentia running as high as 400 ounces to the ton. At Laun, in mining lead ore many years ago, a pocket, or "vugh," was met with, containing loose earthy chloride of silver, with native silver, and a little proustite, or ruby silver.

The silver contained in the Tilt Cove ore was saved along with the gold, but we have no statistics of the amount.

Coal Deposits.

A great deal has been said and written about our coal deposits, mostly of an unreliable character, and coming from persons who knew little or nothing about the subject. It may prove of interest if a plain statement of the actual facts be made by one who has had most to do with the exploration of these coal fields.

There are in Newfoundland three distinct carboniferous areas, one in the Codroy Valley, another in the country lying to the south of Bay St. George, and the third on the upper reaches of the Humber River, in the region extending between Grand and Sandy Lakes. The first named is of very limited extent, being a mere segment of a trough cut off by a great fault. There are two little patches of about a mile each in longitudinal extent, but the greatest thickness of the true coal measures does not exceed 250 to 300

feet in all. Nevertheless, within these narrow limits, there are six seams of coal, all standing in a vertical position. Four of the six seams were of small dimensions, but the remaining two were quite large. One, at its outcrop, showed 9½ feet of good solid coal, while the other, at one point, was 23 feet wide, consisting of layers of coal, shale and clay, and containing 15 feet fairly good coal. They did not however maintain anything like this thickness throughout, but were found to vary very considerably; the first had dwindled down to 5 feet with only three feet of coal, while the larger seam, which was uncovered at five different places along its strike, gave an average thickness of 7½ feet. The nine foot seam was drifted upon for ninety feet, and about 100 tons taken out. Some of this coal was used by the Railway Company on their locomotive with excellent results as a steam producer. It was found however, in running the drift, that the seam soon became pinched up to about three feet, after which it widened out again to 6½ feet, but at the end of the drift ran chiefly into shale.

The Bay St. George coal area is in the form of a narrow trough, situated some eight miles inland from the south shore of the bay. It strikes generally about N.80° E. S. 80° W. magnetic, being almost parallel with the coast line. The full extent of this trough is not yet known, but it has been traced for about five miles longitudinally. Three brooks which have cut channels across it, afford the only available sections of the measures. On the most westerly of these, called Middle Barachois, a good section of two miles in extent is exposed. On stripping this section with pick and shovel, twelve separate coal seams were revealed on the north side of the trough, and most of these were again uncovered on the opposite side, dipping towards the former. The seams ranged in thickness from a few inches up to over five feet, and the coal in several was of first class quality. On Robinson's River, two miles further east, and on a tributary of the latter, two and a half miles still further east, small exposures of the coal measures are again met with. The Robinson's River section contained three seams, one of which showed a thickness of 4′2″ good solid coal, and on the Northern Feeder, four seams were uncovered. Only one of these was of any importance. Although but 1′6″ in thickness, this coal was of an exceptionally superior quality, being clean,

solid, bright and semi-anthracitic in character. It is low in sulphur and ash, and burns with a clear flame in the open grate.

The coal seams so far known in this trough, averaging one foot and upwards, are as follows:—

	Feet	Inches.	
Murray seam	5	4	On the Barachois River.
Rocky "	1	5	
Clay "	1	8	
Slaty "	1	4	
18 inch "	1	6	
Jukes "	4	6	
Cleary "	2	2	
Howley "	4	2	on Robinson's River.
Shears "	1	2	on Northern Feeder.

The aggregate thickness of all the seams in this trough is 27 feet, which, should they maintain their average throughout, give as a result, 25,920,000 tons of coal, for every mile of superficial area they may be found to underlie.

In the Humber Valley, the Carboniferous series spreads over fully five hundred square miles of country, but by far the greater portion of which is occupied by the lower and unproductive members of the series. Here, again, the true coal measures are confined to a long narrow trough which extends along the south side of the Grand Lake, towards its head, and thence strikes Northeasterly into the flat country, lying between Grand and Sandy Lakes. This trough has now been traced over 11 miles on its strike and in all probability it terminates in Sandy Lake, some 6 or 7 miles further on.

The country hereabout is very difficult to explore, owing to the immense accumulation of superficial debris, in the shape of boulders, gravel and sand, spread all over the surface, which effectually conceals the structure beneath. Of late years the Calyx boring drill has been brought into requisition, to test this coal field, and we are gradually acquiring a better knowledge of its extent and possibilities.

What has been ascertained up to the present time is briefly as follows:—One small section was uncovered with pick and shovel

on Aldery Brook, south side of Grand Lake, two miles from its head. Here the trough is very narrow, and lies up against the Laurentian Hill range. It does not exceed a quarter of a mile in width, yet it contains 30 outcrops of coal, crowded together, which on account of the doubling up of the strata, assume a nearly vertical position, and in reality represent 15 distinct seams. They vary in thickness from a few inches up to 6½ feet.

The largest seam was drifted upon for 150 feet and a good deal of coal of a superior quality taken out. Several of the others also were partly opened up, and yielded some excellent coal. Six seams in this section showed, at their outcrops, the following dimensions.:—

One seam	2′	0″.
"	1′	6″.
"	1′	8″.
"	6′	6″.
"	3′	0″.
"	2′	6″.

A mile and a half further east, on Coal Brook, eighteen outcrops were observed, representing nine separate seams. Here the trough begins to widen somewhat, and the seams dip at an angle of about 50°. Six of these gave a thickness each of:—

One seam	1′	4″.
"	3′	5″.
"	1′	0″.
"	1′	6″.
"	2′	4″.
"	1′	0″.

The 3′ 5″ seam was mined to a considerable extent by the Messrs. Reid, railway contractors, in 1898–99, and about 8,000 tons of coal extracted, all of which was used on their trains.

On Kelvin Brook, two and a half miles still further east, a small section only, on the south side of the trough, exhibited six seams of coal, three of which showed 3′ 8″, 2′ 6″, and 6′ 2″ respectively. Three and three-quarter miles on the line of strike eastward, and where the railway crosses the trough, near Goose Brook, three seams were discovered by sinking pits through the

gravel, &c. The lowest in the section contained 2′ 6″, the next higher up 3′ 4″, and the third 1′ 6″. These were all on the south side of the trough, dipping nearly north, at a much lower angle of inclination, which indicated a considerable widening out of the measures.

The 3′ 4″ seam here was also sunk upon by the Messrs. Reid, and quite a lot of coal was taken out.

Owing to the utter impossibility of doing any further effective work with pick and shovel in this region, recourse was next had to the boring rod. During the past few years, ten holes were put down at short intervals apart, which resulted in finding several new seams. Last year and the year previous, eighteen seams were bored through. Most of these were quite small, six only ranging from one foot upwards, being as follows:—3′ 0″, 2′ 6″, 1′ 0″, 2′ 4″, 1′ 0″, and 1′ 6″.

Much remains to be accomplished before the full extent and importance of this promising coal field is thoroughly worked out, but enough is known to warrant the assumption that here we have a possible asset of great future value to this country. The writer would not, at present, attempt even an approximate estimate of the probable amount of available coal within this area, but has no hesitation in pronouncing the opinion that it must amount to many millions of tons. Appended are a few assays of the coals made some years ago, which will give some idea of their composition, &c.

FROM BAY ST. GEORGE.

	Cleary seam	Jukes seam	Howley seam
Moisture	3.548	3.036	2.784
Volatile matter	30.897	30.344	29.271
Fixed carbon	55.229	60.142	54.462
Sulphur	3.946	1.963	3.047
Ash	6.380	4.515	10.430
	100.000	100.000	100.000

FROM ALDERY BROOK, GRAND LAKE

	No. 2	No. 6	No. 7	No. 9
Moisture	10.22	5.80	10.77	13 71
Volatile matter	24.39	31.44	16.55	26.83
Fixed carbon	48.51	57.86	33.89	51.06
Ash	15.72	4.08	37.86	7.56
Sulphur	1.16	.82	.93	.84
	100.00	100.00	100.00	100.00
Coke (in closed vessel)	65.39	62.76	72.68	59.56

FROM ALDERY BROOK.

	No. 15	No. 16	No. 17	No. 20
Moisture	15.78	5.82	4.32	7.41
Volatile matter	30.30	33.62	16.84	30.73
Fixed carbon	45.29	55.28	72.66	53.49
Ash	8.08	4.49	5.33	7.71
Sulphur	.55	.79	.85	66
	100.00	100.00	100.00	100.00
Coke (in closed vessel)	33.92	60.56	78.84	61.86

FROM COAL BROOK. KELVIN BROOK.

	No. 3	No. 4	No. 1
Moisture	9.93	5.02	8.44
Volatile matter	24.01	31.25	28.54
Fixed carbon	49.15	54.03	50.07
Ash	16.14	8.66	11.53
Sulphur	.77	1.04	1.42
	100.00	100.00	100.00
Coke (in closed vessel)	66.06	63.73	63.92

OTHER NON-METALLICS.

It is needful to but merely mention the occurrence of other non-metallic substances of value, few of which have received any attention up to the present time, while others have been exploited in a small way only. These comprise:—Asbestos, Barytes, Feldspar, Garnet, Graphite, Grindstones, Gypsum, Honestones, Infusorial earths, Kaolin, Lithographic stones, Mica, Petroleum, Salt, Slate, Steatite and Talc.

In 1902-3-4, there were shipped some 6,615 tons of barytes, and in 1904-5, 6,000 tons of talc. In 1904, the Parson's Pond Oil fields produced 700 bbls. petroleum, but a much larger quantity has been pumped from the wells from time to time, of which there is no record. Last year, several hundred barrels were utilized at the gas works in St. John's to enrich the gas production of the coal used, with most encouraging results.

The slate of this country is of superior excellence, and has been pronounced fully equal to that of Carnarvonshire, Wales, by those competent to judge. It fetches in England, the highest price of any imported slate. It is an abundant material, and is found in large quantity, both on the east and west sides of the island. A quantity of first class slate has been quarried in Trinity Bay during a number of years past. Recently, a new quarry has been opened at Humber Arm, Bay of Islands, and the slate manufactured therefrom is, if anything, superior to that turned out in Trinity Bay. So far no attempt has been made to utilize this material, other than for roofing purposes, but there is no doubt it is equally suitable for any other purpose to which slate is applicable.

Between the years 1865 and the present date, some 153,702 squares of roofing slate have been manufactured at these quarries, but a very small percentage of this was used locally, nearly all of it going to the English markets, where it found ready sale.

Most of this slate is of a dark purple, but there is some of it of a reddish, and also some of a pale unfading green colour. It has been pronounced the best slate in America.

An infinite variety of building and ornamental stones are found here, such as granites, porphyries, sandstones, freestones, limestones, soapstones, marble, of many shades of colour, serpentine, &c.

Pipe clays, brick clays, fire clays, terra cotta clay, kaolin, red and yellow ochres, and a variety of other substances likely some day to become of economic importance, go to make up the sum total of the known mineral resources of this, England's oldest colonial possession.

A
B
C
C
B
C
B

SKETCH MAP OF NEWFOUNDLAND, SHOWING MAIN GEOLOGICAL FORMATIONS.

MINERAL DEPOSITS OF THE SERPENTINE BELT OF SOUTHERN QUEBEC.

By John A. Dresser, McGill University, Montreal.

(Published by permission of the Director of the Geological Survey of Canada.)

(Annual Meeting, Montreal, 1909.)

I. General.

For the past few years practically one-half of the mineral output of the Province of Quebec has been obtained from the area in the Eastern Townships known as the serpentine belt. This is a complex of igneous and metamorphic rocks consisting of peridotite, pyroxenite, diabase and granite, with serpentine and talc schists. It is rather because of the greater economic importance of the serpentine and the fact that it is a rock more easily recognized, than on account of its relative area, that the name serpentine is commonly applied to the group.

These rocks form part of a series which extends, with some interruptions, in a line parallel to the Atlantic coast from Georgia to Newfoundland. In the Province of Quebec they are almost continuous from the international boundary line near Lake Memphremagog to Thetford Mines. Beyond this to the northeastward they appear frequently for a distance of eighty miles in the counties of Beauce, Dorchester, Bellechasse, Montmagny and L'Islet, and after an interval of some 120 miles they reappear with a large development in the Shickshock mountains of Gaspe. They are best known in the counties of Megantic, Wolfe, Richmond, Sherbrooke, Shefford and Brome.

The present output of asbestos comes from the counties of Megantic and Richmond; of chromic iron from Megantic and Wolfe. In each case the county of Megantic furnishes the principal production.

II. GEOLOGY.

The geological relations of the serpentines and associated rocks are not yet very completely known. They are, however, an intrusive series, the latest of which cut sedimentary strata of mid-

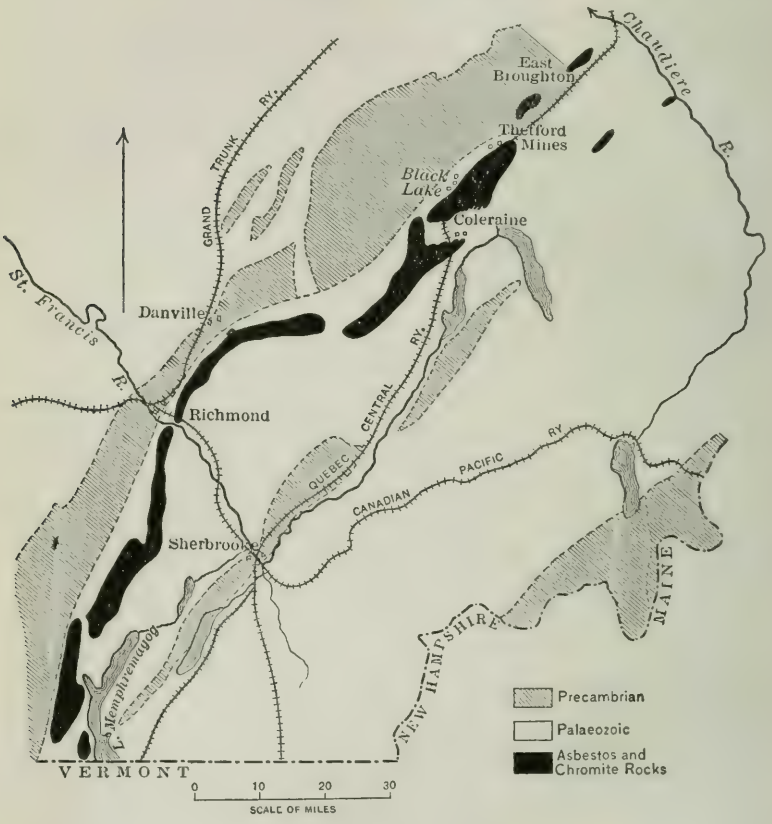


Fig. 1.

dle Ordovician age. Some portions seem to be laccolites uncovered by denudation, while others are probably extrusive masses with plutonic rocks in the central portions which pass into diabase towards the sides and top, and have since been deeply eroded. The whole series has been much folded and deformed by regional metamorphism.

The peridotite and pyroxenite are parts of one original mass, which have been differentiated from each other. The serpentine in the Thetford-Black Lake and Danville districts has originated from the alteration of the peridotite. That of the East Broughton and related occurrence has apparently been derived from a very similar rock, but is in a much more advanced stage of alteration and doubtless is much older. Isolated outcrops of this older serpentine appear at various places in the counties of Wolfe, Megantic and Lotbiniere, and are probably portions of a partially uncovered large mass, or bathylith, at least fifty miles long and fifteen in width, underlying a great part of the dome-shaped hilly country between the Quebec Central and the Grand Trunk Railways in this district. This serpentine is probably of Pre-Cambrian age.

The diabase forms a marginal or outer facies of the peridotites and pyroxenites in some parts of the district, but in others it cuts serpentine that is thought to belong to the later of the two classes of that rock that have been mentioned. Further field work is necessary to define the precise relations of these rocks. The diabase occupies much the greater portion of the entire belt, and also forms all the higher hills, such as Broughton, Adstock, Ham, Orford and Owls Head mountains.

A peculiar hornblende granite cuts these rocks with numerous dykes and is otherwise intimately associated with them.

Mineral deposits of importance are found in this district in each of the above mentioned rocks except the last. Asbestos occurs in the serpentine; chromic iron in serpentine and peridotite; talc in the pyroxenite; and associated with the diabase there are copper, antimony and nickel.

III. Asbestos.

Although asbestos was known in the Eastern Townships as early as 1847, it was not until thirty years later that it became commercially important. Work was begun in 1877 at Thetford and almost at the same time at Black Lake and Danville, and has steadily advanced ever since. The mineral, which is the chrysotile variety of asbestos, fibrous serpentine, requires no description. It has the same chemical composition as the rock which contains it. It is valuable for the property of being incombustible, and

that it is a most successful non-conductor of heat and electricity, and well resists most acids. It is used for an increasingly large number of purposes every year, such as stage curtains, fire screens, boiler covering, fireproof roofing and covering, insulating material, &c., &c. The product has hitherto been manufactured in the United States and in Europe, but at present large works for the manufacture of asbestos are being installed in Canada.

1. *Production.*—Asbestos mining is now the most important mineral industry in the Province of Quebec. During the last thirty years, that is, since asbestos mining began, the aggregate production has had a value of more than twenty million dollars, and at the present time the Province of Quebec produces between 85% and 90% of the world's supply. This entire amount, in value two and a-half million dollars, is obtained from the counties of Megantic and Richmond, much the greater part coming from the former. The following returns of production indicate the growth of the industry. The production of low grade material was greatly increased by the introduction of mechanical concentration in 1892-3-4, and the effect is well shown in the statistics which are taken from the returns of the Geological Survey of Canada.

	Production.		Value.
1878—	50	tons.....	$ ———
1879—	300	"	19,500
1880—	380	"	24,700
1881—	540	"	35,100
1882—	810	"	52,650
1883—	955	"	68,750
1884—	1,141	"	75,097
1885—	2,440	"	142,441
1886—	3,458	"	206,251
1887—	4,619	"	226,976
1888—	4,404	"	255,007
1889—	6,113	"	426,554
1890—	9,860	"	1,260,240
1891—	9,279	"	999,878
1892—	6,082	"	390,462
1893—	6,331	"	310,156
1894—	7,630	"	420,825

Production.		Value.
1895— 8,756	tons.....	$ 368,175
1896—10,892	"	423,066
1897—13,202	"	399,528
1898—16,124	"	475,131
1899—17,790	"	468,635
1900—21,621	"	729,886
1901—32,892	"	1,248,645
1902—30,219	"	1,126,688
1903—31,129	"	915,888
1904—35,611	"	1,213,502
1905—50,669	"	1,486,359
1906—60,761	"	2,036,428
1907—62,241	"	2,484,768
1908—65,534	"	2,547,507

2. *Distribution of the Deposits.*—In the Thetford and Danville areas workable asbestos has as yet been found only in the north-western parts. The areas of serpentine in these two localities are not connected at the surface, but being lithologically similar and both intrusive, it is probable that they are portions of one general mass and so are connected at no great depth beneath the surface. The rocks of each of these localities ranges from peridotite, rich in olivine, to pyroxenite, in which little olivine occurs. There is also much diabase in both areas. The peridotite is largely altered to serpentine, but it is in the latter only that asbestos occurs. In the cooling of the peridotite-pyroxenite magma there appears to have been a segregation of olivine towards the north-western edge of the mass, and of pyroxene towards the south-east side.

The greater part of the entire rock mass is most suitably called serpentine, but much of it carries from 10% to 20% of pyroxene, generally bronzite, and forms a hard rock which the miners call "dry" or "bastard" serpentine, or "hornblende rock." The "heads" or masses of hard rock often met with in the asbestos mines are of the same character. On the other hand the more pure serpentine which produces asbestos is distinguished by a softness of feel and a more uniformly light colour. The original rock in this case was richer in olivine and poorer in pyroxene, and probably contained less chromite, which is disseminated more or less freely through all of this rock mass.

The distribution of the asbestos bearing portions of the serpentine, therefore, seems to depend on differentiation in the primary rock, by which a relatively small proportion of it became rich enough in olivine to form a comparatively pure serpentine. While the productive portions are small in proportion to the entire body of serpentine, they nevertheless form asbestos deposits that are practically inexhaustible.

3. *Character of the Veins.*—The asbestos occurs in gash veins, which rarely reach three inches in width or exceed two hundred feet in length. The great majority are less than three-quarters of an inch wide and are only a few feet in length. The fibres of asbestos run transversely to the veins, and hence perpendicularly to the side walls. Thin films of iron ore, sometimes chromite, but more frequently magnetite, often form partings in the vein, or coat the ends of the fibres.

4. *Origin of the Veins.*—The identity in composition of asbestos and serpentine and the evident vein structure show that the material of the veins has come from the side walls. But while all investigators have practically agreed upon the source of the material of the veins, there has been less unanimity in the opinions that have been expressed as to how the veins were formed, and more especially as to the origin of the fissures.

The serpentine is generally much fractured and slickensided along the fracture planes. The late T. Sterry Hunt attributed this in a great measure to the increase of volume which would accompany the change of the anhydrous silicate, olivine, to the hydrous silicate, serpentine. The slickensided fracture planes, however, are less frequently walls of asbestos veins, and consequently this observation does not apply to the origin of these veins.

J. H. Pratt (U.S.G.S., 1904) says that "the original rock in cooling would solidify first along its contact with the rocks through which it had penetrated and where it was in contact with any included masses of the country rock, that had been broken off during the intrusion of the molten magma. The outer portions of the molten rock would thus cool much more suddenly than the interior portions and there would be a tendency for them to develop cracks and parting planes. In the alteration of these pri-

mary rocks to serpentine, through the agency of aqueous solutions, vapours, &c., there would be perhaps, to some extent at least, a widening of these cracks, but in the end they would be filled with serpentine deposited from aqueous solutions from their walls, and the resulting fibrous structure of the serpentine filling these seams represents the nearest approach to a true crystallization that the mineral serpentine assumes, except when it is found as pseudomorph after another mineral."

G. P. Merrill, Smithsonian Institution, Washington, D.C., (*Mining World*, 1905), attributes the fracturing to shrinkage due to the partial dehydration of the serpentine, and also to loss of silica, as has been suggested by J. F. Kemp (N.Y. Acad. Sci., 1901), comparing the veins to the shrinkage cracks in serpentine nodules. He considers the asbestos fibres to have grown from one or both sides of the vein, according as it is an undivided or a divided vein.

R. W. Ells (Bulletin on Asbestos, 1903, Geological Survey of Canada) says of asbestos veins: "In whatever way the fissures were caused, and it is very probable that they have been formed by the great processes of metamorphism to which the rocks were exposed in the change from dioritic matter to serpentine, the vein asbestos appears more naturally to have been produced by a process of segregation of serpentinous matter from the sides of the fissures very much as ordinary quartz in mineral veins is known to have been produced."

F. Cirkel ("Asbestos, its Occurrence, Exploitation and Uses," Department of Mines, Ottawa, 1905) agrees in part with Messrs. Merrill and Kemp, but considers a part of the fracturing to have been caused by the intrusion of granite dykes which are numerous in the district. He also considers the veins to have been successively filled from the side walls.

A. P. Low (Geological Survey of Canada, 1906, The Chibougamou Mining Region) says: "The cracks were probably formed by shrinkage of the mass andperhaps in part by the crushing action of the same pressure which lengthened and flattened the serpentine areas, and at the same time made the associated rocks schistose. The asbestos appears to the writer to have been deposited in the cracks under great pressure from superheated waters which, penetrating the rock, absorbed the material of the serpentine until the solution became a saturated one. With cooling the mineral would

be deposited in the cracks. . . . In the Thetford and Black Lake areas, masses and dykes of granite have been intruded into the serpentine and these probably account for the necessary pressure and heated waters to form the asbestos there."

An important feature of asbestos veins, that seems to have been generally overlooked, is that the wall rock adjacent to the vein is always completely reduced to serpentine, while the general mass of the country rock is usually not so far altered. In all the deposits, except those of the East Broughton type, the asbestos-bearing rock is only partially altered to serpentine, except along the asbestos veins, and here the alteration appears to be invariably complete. A band of pure serpentine extends on each side of the asbestos vein to a width generally about three times that of the vein. Measurements were taken on forty-nine veins in the Bell and Johnson mines and the average ratio width of the asbestos vein to the total band of asbestos and bordering serpentine was 1:6.6, seventeen of the forty-nine measurements practically coinciding with this average. The serpentine border is not easily noticeable in fresh rock, but is very conspicuous on the faces of workings which have had fifteen or twenty years' exposure to the weather, and can often be well seen on unworked surfaces (Figs. 2 and 3).

The veins occur in the joint planes of the original rock, in fractures produced by regional metamorphism, and often in the crevices formed when shells are being cast off rectangular blocks as in weathering. All three types of fissures are indicated by the veins in figure 2, which is a drawing of a wall of a pit near the Standard mine. At the junction of two veins, one, usually the wider, sometimes cuts the other distinctly, but more frequently they coalesce with a short line of division between them, marked by a film of iron.

While the veins run in all directions through the rock, the larger veins are usually those along joint planes. Of these the horizontal series, which are sometimes over two inches wide and extend for 100 to 200 feet, could never have been open fissures, nor is it conceivable that small areas of rich ground occasionally found where there may be 12% or 14% of asbestos could ever have had as many open fissures as they now have filled veins. It therefore seems most probable that a process of replacement of the wall rock

has gone on contemporaneously with the deposition of the asbestos. The film of iron ore, or the parting so common in the veins, would thus be the beginning of the vein, and chrysotile crystals by growing outward on either side would thus have formed the wider veins as the serpentinization of the wall rock advanced. The asbestos can

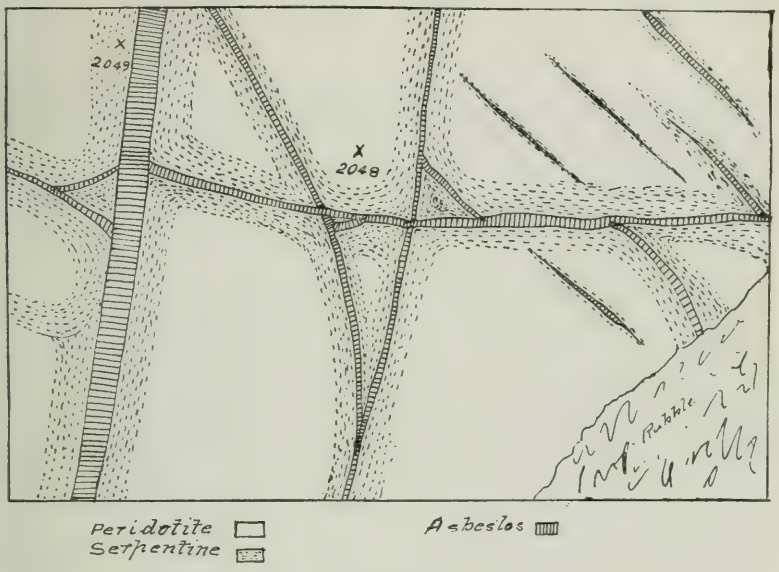


Fig. 2.

Diagram showing asbestos and serpentine in peridotite.—Drawn by R.R. Rose. The largest vein is two inches wide.

only have been formed after the serpentinization of adjacent parts of the rock.

Pratt (op. cit.) observed that "It is probable that this chrysotile asbestos may have been formed some time before the complete alteration of the primary rock into serpentine. This is emphasized by the fact that in the southern part of the United States, where these magnesian rocks have been but partly altered to serpentine, seams of chrysotile asbestos are occasionally found almost entirely enclosed by a peridotite rock, altered but little to serpentine." In the case shown in Figure 2, a microscopic examination of the rock from the two portions marked No. 2048

and No. 2049, showed the latter to be wholly serpentine, the former a fairly fresh peridotite. Figures 4 and 5 show microphotographs of these sections.

At East Broughton and other localities on the older serpentine, the entire rock is of the character of the vein borders at Thetford.

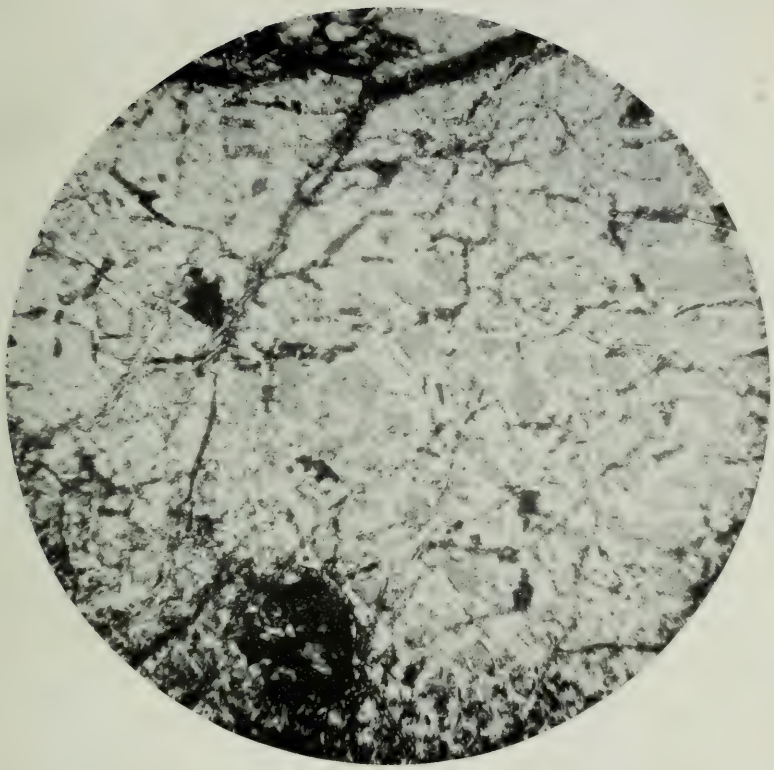
The entire rock being serpentinized, the proportion of veins is large. Asbestos seems to have reached its maximum development which, from the measurements made at Thetford, would represent nearly one-seventh or upwards of 15% of the serpentine. But this rock has passed its maximum stage of productive value, for an alteration of the larger veins has begun, by which the fibres of asbestos are partially replaced by calcite. Their flexibility and tensile strength being gone, they are no longer products of value. The best asbestos of this locality seems to be in the smaller veins. The rock is exceedingly soft, and the proportion of vein matter is so great that practically all of the rock mined goes to the mill. The fact that the asbestos is of better quality in the narrow veins than in the larger ones appears to corroborate the view that the asbestos veins are gradually formed. Beginning along the joint planes, they extend to all parts of the rock as fracturing from any cause opens it to the action of metamorphosing agencies, principally water. These have reduced it first to serpentine, second, to asbestos, and lastly, forming a sort of ophicalcite.

Mr. W. S. Johnson states that veins of asbestos partially replaced by calcite are occasionally found at Coleraine. In that case, the Thetford area may be regarded as having reached the maximum productive value for asbestos.

According to the measurements mentioned above, this should be nearly 15%. While this is in excess of the actual production of the rock as a whole, small very productive parts probably reach 12% to 14% occasionally, which, allowing for loss in recovery, accords fairly well with the results of the limited number of measurements on which this estimate of possible proportion of asbestos to serpentine is based.

5. *The Granite.*—The presence of granite in dykes or other forms has been considered by many to be favourable, if not necessary, to the occurrence of rich asbestos ground. Yet in the older serpentine at East Broughton the recent development of numerous areas now rich and formerly much richer, has not, so far as the

Fig. 3.
Showing veins of asbestos within band of serpentine on weathered surface of peridotite.



(*Photomicrograph made by R Harvie.*)

Fig. 4.

Photomicrograph of specimen 2048. Rock about 90% olivine. Olivine grains surrounded by narrow veins of serpentine; a vein of asbestos; and a crystal pyroxene.

writer is aware, disclosed any granite in that district. It would not therefore appear to be necessary to the existence of asbestos.

Where the granite is intrusive, as in parts of the Thetford and Danville districts, the effect in fracturing the serpentine is highly probable, and the influence of heated waters accompanying the intrusion, as suggested by Dr. Low, is likely to have hastened the process of serpentinization and the consequent formation of asbestos. But much of the granite appears to be nearly, if not quite, contemporaneous with the parent rock of the serpentine. It forms isolated masses of even grain, is separated from the serpentine by intermediate rock matter, and seems, from such evidence as is available, to be an extreme differentiation product complementary to the very basic peridotite. This view, which is as yet only tentatively advanced owing to lack of sufficient field study, seems also to be corroborated by the fact that the granite is less frequently found in parts of the rock rich in pyroxene than in those having much olivine.

IV. Chromite.

Chromic iron, valuable not for its iron but for its content of chromic oxide, occurs very generally in the peridotite and the serpentine of the Thetford, Black Lake and Danville type. The chief production is as yet from the counties of Megantic and Wolfe, the former producing much the greater amount.

The placing of the industry on a substantial commercial basis has been largely due to the vigorous operations of the Black Lake Chrome and Asbestos Company, who are as yet the principal producers.

1. *Production.*—As early as 1861 samples of some tons' weight were shipped from Ham, in the county of Wolfe, to London and Glasgow, but no mining resulted, probably owing to the undeveloped state of the country, as the price of chromite was at that time four or five times higher than at present. In 1886 and 1887 another attempt was made to exploit the chromite ores of Quebec by Dr. James Reed, who shipped 100 tons from Wolfestown, Leeds and Thetford to Philadelphia. No further shipments seem to have been made until 1894 when operations were begun at several points and 1,000 tons of ore were shipped. The returns of the Geological Survey record a production since

that date valued at over $600,000. The output of the last six years is as follows:—

	Production.	Value.
1903	3509 tons.	$ 51,121
1904	6074 "	67,146
1905	8528 "	104,565
1906	8750 "	92,100
1907	7196 "	72,091
1908	7225 "	82,008

Canada, the total production of which is from this district, stands fourth among the countries of the world in the production of chromic iron, and furnishes about 10% of the world's output. The three leading countries are:

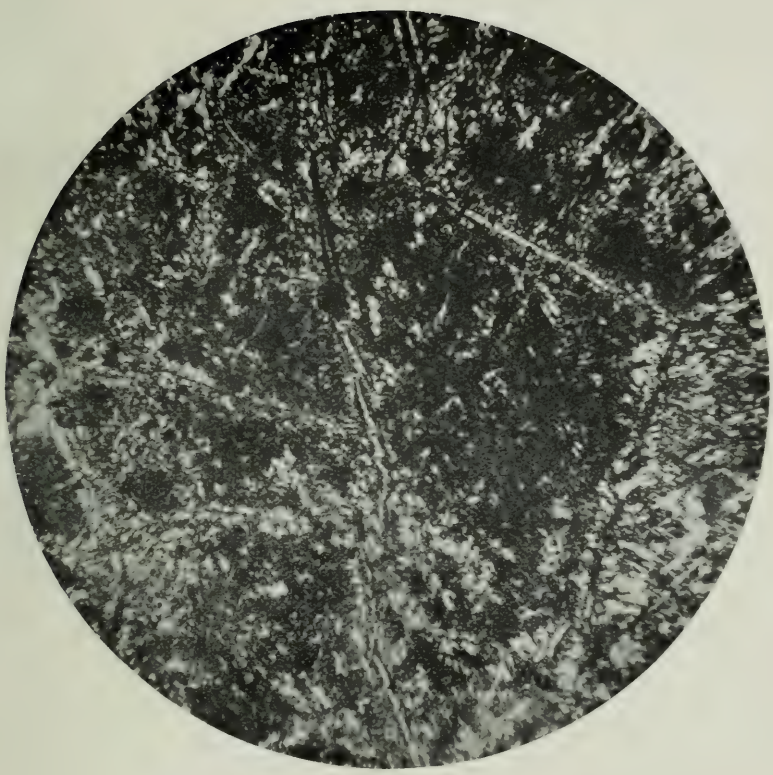
New Caledonia	51,000 tons
Russia	20,000 "
Greece	15,000 "

Turkey, the United States and New South Wales produce smaller amounts. Turkey is reported to have large deposits of a good quality of ore, but the lack of railway or water transportation makes mining practically prohibitive at present prices.

A limited quantity of the Canadian ore has been used by the Electric Reduction Company of Buckingham, Quebec, in the manufacture of ferro-chrome. The remainder, except for occasional shipments to Europe, is shipped to the United States. It is there used for the manufacture of bichromates for use in dyeing textiles, tanning leather, for pigments in printing and painting; in making chrome steel; and lower grades for furnace linings.

2. *Distribution of the Deposits.*—The ore is found in the serpentine and peridotite, in some parts in large bodies of ore, in others, in mere nodules, while grains of chromite are frequently scattered through all parts of these rocks. The general dissemination of ore throughout the rock, together with the highly altered and disturbed condition of the latter, would suggest that the ore bodies have been formed by concentration of ore from the surrounding rock, but detailed examination does not support this view.

The walls of the ore bodies are not usually well defined, and grains of chromite are quite as plentifully disseminated in



(*Photomicrograph made by R. Harvie.*)

Fig. 5.

Photomicrograph of specimen 2049. Serpentine, and a few grains of chromite.

the wall rock near the ore bodies as elsewhere. The deposits are irregular in shape though they commonly have an approach to ellipsoidal outlines in a surface section, indicating that they are more or less lens-shaped. The longer axes lie parallel to the lines of fracture or cleavage in the country rock, that is, in a north-east and south-west direction, and so the form may be due to regional pressure which has been exerted on the ore bodies since they were formed. The majority of the ore bodies yet found are near, but rarely at, the contact of the serpentine, or peridotite, with adjacent rocks, and none of importance are far from the contact. There appears to be no definite order in the distribution of the ore bodies, they being separated by bands of the country rock from a few inches to many feet in thickness.

3. *Origin of the Ore Bodies.*—These observations seem to indicate that these ores have originated by primary segregation from the peridotite magma, as was first suggested by Dr. F. D. Adams in a paper presented to the Province of Quebec Mining Association in 1894 ("On the Igneous Origin of Certain Ores"—Trans. Prov. Que. Mining Association, Montreal, 1894). A similar origin has since been established for the chromite ores of the eastern United States by J. H. Pratt (Trans. A.I.ME. 1899), while J. H. L. Vogt (Zeitschrift fur Praktische Geologie, Oct. 1894) had previously shown the chromite of Hestmando, Norway, to be due to primary segregation.

4. *Character of the Ore.*—Chromic iron consists theoretically of an equal number of molecules of chromic and ferrous oxide, answering to the formula FeO, Cr_2O_3, but ore of such purity has not been found in nature except in meteorites. Alumina and magnesia seem to be invariably present, replacing the Cr_2O_3 and the FeO in varying proportions. Following are two analyses by T. Sterry Hunt of specimens regarded by him as typical of the Quebec deposits. (Geology of Canada, 1863, p. 479). They are from the township of Bolton, in the county of Brome, a locality which, although it has not yet produced ore on a commercial basis, seems likely to do so with proper development. Two analyses of chromite, one from Turkey, the other from New Caledonia, are also given for comparison:—

	I.	II.	III.	IV.
	Bolton	Bolton	Turkey	New Caledonia
Cr_2O_3	45.90	49.75	51.70	55.70
Al_2O_3	3.20	11.30	14.10	16.20
FeO	35.38	21.28	14.20	16.60
MgO	15.03	18.13	14.30	9.80
	99.51	100.46		

While the higher magnesia accompanies the lower percentage of iron, as would be expected in a simple replacement of the latter by the former, the higher alumina accompanies the higher chromic oxide. Hence the molecular combinations are more complex than might at first appear.

In discussing the ores of the eastern United States, Mr. Pratt (op. cit.) has suggested that chromite is an isomorphous mixture of three distinct molecules, FeO, Cr_2O_3; MgO, Cr_2O_3; and MgO, Al_2O_3. This hypothesis seems both necessary and sufficient to explain the variations in composition that are found in these ores.

In microscopic sections of ore from Black Lake the chromite is found to consist of two parts—a reddish-brown, translucent substance, and a black, opaque material (fig. 6). Separations of these, which were effected by means of the Wetherill magnetic, and an hydraulic separator with ascending current, showed on analysis of the products a higher percentage of Cr_2O_3 and FeO in the black portion than in the reddish part. Further investigation is being made by the writer on these, and on ores from other parts of the world.

The price of chromite is based on a standard of 50% chromic oxide, lower grades being penalized and those of higher quality being at a premium. Ores carrying less than 40% and as much as 10% are concentrated to 50%, or a little higher. The first class crude ores, or concentrates, rarely exceed 55%, while theoretically pure chromite of the formula FeO, Cr_2O_3 should yield 68%. The difference is evidently due not to defective ore dressing, but to the composition of the ore, which in southern Quebec seems unlikely to be found to contain much above 55% of chromic oxide. As the analysis given above shows, ore from New Caledonia

(*Photomicrograph made by R. Harvie.*) (X Brown, translucent portion.)

Fig. 6.

Photomicrograph of chromite ore.

may have a somewhat higher percentage of Cr_2O_3, but is, as might be expected, lower in magnesia. While these features may make the New Caledonia ore more desirable for the bichromate industry, the higher magnesia probably favours the Quebec ores for use in the manufacture of alloys of steel.

V. Talc.

Talc and soapstone are practically undeveloped resources of the serpentine belt. Many portions of the intrusive rock, being originally rich in pyroxene, have altered to steatite or soapstone, and frequently to a purer variety of talc. These are found principally in connection with the older serpentine of the Broughton series. On lot 2, Craig's Road Range, of the township of Ireland, in the county of Megantic, there is apparently a large deposit of talc of excellent quality. Unfortunately for the development of the property a little copper ore was found on it and the prospectors' attention was turned from opening a promising talc deposit to selling a copper "mine." The property is eleven miles from the Quebec Central Railway at Black Lake.

Within one or two miles of the Quebec Central Railway between Robertson and Broughton stations, there are several small hills of soapstone, some of which probably reach the quality of talc.

Several soapstone quarries have been opened at various times, chiefly for local use, in many parts of the serpentine belt, but no steady industry has as yet resulted.

From the township of Potton, Brome county, a specimen of soapstone was taken which gave the following results in an analysis by T. Sterry Hunt:

	Potton	Pure Talc (Theoretical Composition)
SiO_2	59.60	62.8
MgO	29.15	33.5
FeO	4.50	Usually contains a little iron replacing MgO.

A comparison with the composition of theoretically pure talc, as cited here, indicates a comparatively high grade for the Polton deposits.

VI. COPPER.

Copper occurs in three classes of deposits in the Eastern Townships of Quebec:

1. In the limestones where they are invaded by dykes of igneous rock, as at Acton.

2. In a volcanic series—the porphyries and andesites of Capelton and Harvey Hill.

3. In the diabase of the serpentine series.

It is with this last only that this paper is concerned.

These ores occur in pyrrhotite, while those of the Capelton and Harvey Hill series are in pyrite. In both cases the ore is chalcopyrite and seems to have been introduced later than the pyrite or pyrrhotite bodies that contain them.

The largest of these bodies of copper have been found in the County of Brome, especially in the Townships of Potton and Bolton. The best known is the once famous Huntingdon mine in lot 8, Range VIII of Bolton, which was vigorously operated between 1865 and 1873, while some work has been done more recently. During this period it is reported to have yielded from 200 to 400 tons per month of ore carrying between 7% and 10% of copper. The principal ore body lies in the diabase along its contact with Ordovician slates through which it is intruded. The width of the deposit mined is from eight to fourteen feet. Two miles north of the Huntingdon, on lot 2, Range IX of Bolton, is the Ives mine, which was worked for upwards of ten years. Similar ore bodies have been disclosed by smaller workings between these properties and to the north and the south of them. At the time of working the nearest railway was some twenty-four miles distant, but within the past three years the Orford Mountain Railway has been extended so as to pass in the immediate vicinity of these properties, all of which lie in the valley of the Missisquoi river

Also in the same vicinity and within a little more than a mile from the railway is the Lake Memphremagog mine on lot 28,

Range IX of Potton. This property is on the west slope of Hog's Back Mountain, a diabase hill on the west shore of Lake Memphremagog. The ore is chalcopyrite in pyrite and pyrrhotite, and probably ranges from 1% to 9% copper, with about 35% to 40% iron and nearly the same amount of sulphur. After a period of disuse, this property is now being equipped with plant and will soon again be worked. It is doubtless one of the largest ore bodies in the district.

A deposit of somewhat similar character is found to the north-east of the last in Garthby, near Lac Coulombre, in the County of Wolfe. The ore body here is so covered that its full extent could not be seen, but it is evidently of important size. In the interval of forty-five miles between this and the Lake Memphremagog deposits, several occurrences of similar ore are known. Probably the most important are in the Townships of Orford and Brompton in the Counties of Sherbrooke and Richmond.

At a distance of one hundred miles north-east of Garthby, blocks of diabase carrying pyrrhotite and chalcopyrite were recently found in the Counties of Montmagny and L'Islet. Here the rocks of the serpentine belt occupy some twenty square miles of country, generally wooded, and in which probably no prospecting has ever been done. It is near the line of the projected extension of the Quebec Central Railway from St. George de Beauce to Temiscouata.

VII. Antimony.

Antimony is found in the diabase of the serpentine belt on lot 28 of the first range of South Ham, Wolfe County. It was discovered here in 1863 and has been worked at two periods since that time, first by Mr. W. Russell, of Quebec, and later by the present owner, Dr. James Reed. No statistics of production are available. Two shafts have been sunk, one to a depth of one hundred feet, the bottom of which is reached by an adit some three hundred feet in length. At present no work is being done.

The ore consists of native antimony, valentite or oxide of antimony and a little kermesite, the oxysulphide. It occurs in small veins, the largest about a foot wide, near the contact of diabase with sedimentary slates.

VIII. NICKEL.

Nickel was mined for a time about 1882 on the sixth lot of Range XII of Orford, in the county of Sherbrooke, by the well-known Orford Nickel Company which was organized to operate the property. No records of these operations are available, but the quantity of ore was probably insufficient to make the work successful. Millerite, the sulphide of nickel, occurs here in calcite, but I have not been able to learn whether any other ore of nickel was obtained or not. The locality is now important chiefly for its excellent mineralogical specimens—millerite, ouvarovite and pyroxene—which are to be found in collections in many parts of the world.

CONCLUSION.

There is little detailed information available regarding the serpentine belt in the Shickshock Mountains. The explorations of Dr. A. P. Low and Dr. R. W. Ells, as well as of the earlier geologists of the Geological Survey of Canada, have shown that there is a large development of these rocks. Considerable prospecting for asbestos has probably since been done, but thus far without success. From such information as is available, the district seems likely to contain chromic iron at least, and prospecting for other minerals may yet be attended with success.

Platinum was found in the gravels of the Chaudiere valley many years ago by Sir William Logan. The natural habitat of that mineral is in the peridotites and serpentines, but it has not yet been traced to its source.

As these imperfect notes will have shown, the present knowledge of this complex series of rocks, and the minerals they contain, is very incomplete. Much remains to be learned and applied before the mineral resources of this area can be developed to the limit of their capacity. It is hoped that enough has been said to show that the serpentine belt is a factor of much present importance and of still greater prospective value to the commercial life of the Dominion.

DISCUSSION.

Dr. A. C. Lane:—Prof. Dresser's paper is of great practical interest and importance. We have in Michigan, especially near Ishpeming and Marquette, peridotites with a small amount of chrysotile associated.

Turning to the scientific side,

The separation mentioned by Dresser, p. 167, into a more olivinitic zone, and a more pyroxenic is an interesting parallel to occurrences elsewhere. Most of the Keweenawan lava flows show a most augitic streak about one-third the way up from the bottom. It seems to be a concentration of the most fusible ingredient into the part last consolidated with the effect of gravity co-operating.

J. Volney Lewis has recently described in connection with the Palisades of the Hudson a streak extra rich in olivine. The granite referred to on p.172 as an extreme differentiation product complementary to the very basic peridotite would be analogous to the "red rocks" associated with the Minnesota or Duluth gabbros, and that at Mt. Bohemia and Keweenaw Point. The basic differentiation product complementary might include the iron ores, and it may be worth noting that the Lermondose described by Bastin from Maine*, seems to me from personal inspection to be a similar streak of differentiation of iron ore from a gabbro, the contact being not far from it. In this respect it is like the chromite deposits described by Dresser, p. 173. He has accurately remarked that they are near but not at the contact. It must not be forgotten that in a great Plutonic mass, heated much above the crystallization point, the contact will begin its cooling at a temperature half way between the initial temperature of the magma and that of the country rock, and that if the conditions of crystallization are nearer the initial conditions of the magma than those of the country rock, that is above this half way point, there will, close to the contact, be a rind that crystallizes and con-

* Journal of Geology, 1908, p. 124.

solidates rapidly, without much differentiation. As the contact zone heats up the cooling through this range of conditions will be very much slower for a belt a certain distance in from the contact. There will therefore be plenty of time in this belt for the earlier formed minerals to crystalize, and as they are formed and removed from the solution (perhaps collected together by gravity) for further supplies of the same ingredients to be diffused from the hotter center.

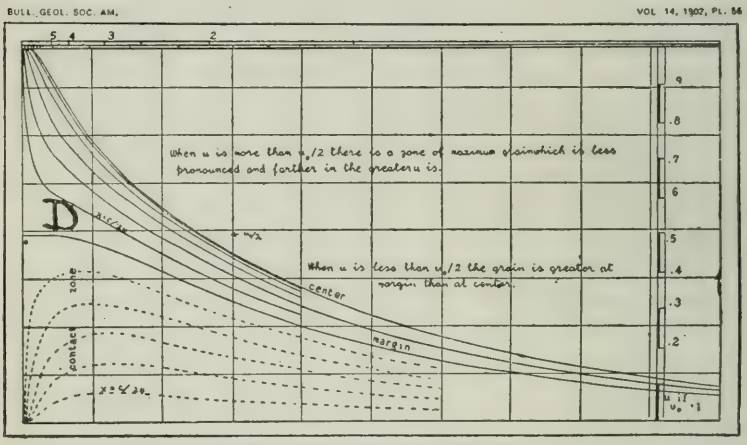

BULL. GEOL. SOC. AM.
VOL. 14, 1902, PL. 56
When u is more than u₀/2 there is a zone of maximum grain which is less pronounced and farther in the greater u is.
When u is less than u₀/2 the grain is greater at margin than at center.
center
margin
CONTACT ZONE
CURVES OF COOLING—EFFECTIVE CONTACT ZONE BROAD

FIG. 1.

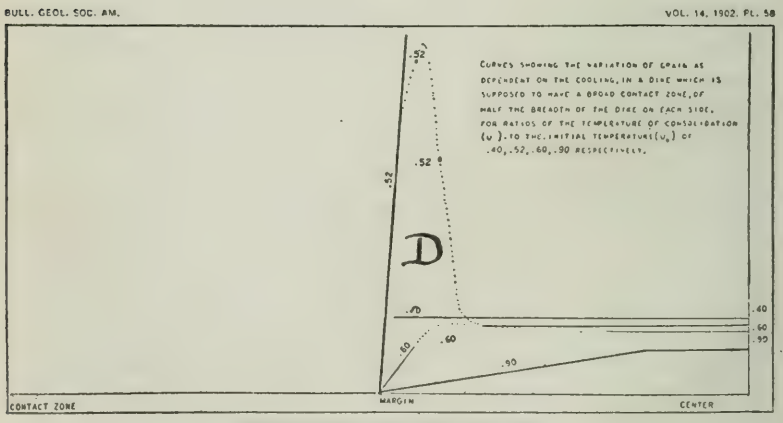

BULL. GEOL. SOC. AM.
VOL. 14, 1902, PL. 58
CURVES SHOWING THE VARIATION OF GRAIN AS DEPENDENT ON THE COOLING, IN A DIKE WHICH IS SUPPOSED TO HAVE A BROAD CONTACT ZONE, OF HALF THE BREADTH OF THE DIKE ON EACH SIDE. FOR RATIOS OF THE TEMPERATURE OF CONSOLIDATION (u) TO THE INITIAL TEMPERATURE (u₀) OF .40, .52, .60, .90 RESPECTIVELY.
.32
.52
.60
.90
CONTACT ZONE
MARGIN
CENTER
TANGENTS TO CURVES OF GRAIN - BROAD CONTACT ZONE

FIG. 2 Similar to Fig. 4, but illustrating the variation in grain in case the contact zone is broad. It stands in the same relation to Fig. 3 that Fig. 4 does to Fig. 2.

The general place and time of this differentiation is shown by D in the accompanying diagrams, which show the cooling of an intrusive sheet with a contact zone of equal breadth, divided half on each side, and also the grain of the same sheet supposing that consolidation takes place at different temperatures.

Mr. Dresser:—Since the above paper was published in the Bulletin of this Institute, Mr. R. W. Brock, Director of the Geological Survey of Canada, has shown the writer the manuscript of a paper prepared in 1906–7 by Mr. W. J. Woolsey, when a student at Mining School, Kingston, Ont., and who is now a mining engineer at Thetford Mines. In this paper Mr. Woolsey showed that the asbestos veins are formed by growth outward from the walls of a fissure, or are "exogenous," and he clearly demonstrated this fact by a well chosen microphotograph. Mr. Woolsey also expressed the opinion that the amount of asbestos present is in direct proportion to the serpentinization of the parent rock.

The duties of the editorial committee are always delicate and often difficult; but it is certainly unfortunate that it did not see fit to publish this paper in some form or other. In the original character of the observations, and in the importance and interest of the conclusions it would have formed a contribution of value to the Journal of the Institute.

Note—For further discussion on Mr. Dresser's paper see Appendix.

THE CHIBOGOMOU REGION, PROVINCE OF QUEBEC.

By E. DULIEUX, Ecole Polytechnique, Montreal.

(Annual Meeting, Montreal, March, 1909.)

The district of Lake Chibogomou was described as early as 1870, by Mr. James Richardson, as containing iron, copper and serpentine. To the remoteness of this region—situated as much as ten days' journey by canoe from Lake St. John—is due the fact that no prospecting expedition was organized till 1903, when Mr. Peter Mackenzie discovered asbestos on an island near a centre of magnetic attraction, where he was searching for iron. A short time after, he discovered copper pyrites and outcrops of auriferous quartz on Portage Island. Mr. Obalski, Superintendent of Mines for the Province of Quebec, made in the following year a trip to the Chibogomou. In the report which he published on the subject he chronicled these discoveries, and declared that in view of the natural advantages of the district the establishment of a railway, to afford communication with the trunk systems, should be considered.

After the publication of this report, numerous prospectors in their turn explored the northern shores of Lake Chibogomou, and the neighbourhoods of lakes Doré, Bourbeau, David, Simon and Assinibastats. In the month of August, 1908, the government of the Province of Quebec sent out a second expedition and entrusted to the writer the task of examining the nature of the discoveries made, and of considering the possibility of uniting the district of Chibogomou to Roberval by a line of railway.

THE GEOLOGY OF THE REGION.

The region of Lake Chibogomou consists of a belt of rocks chiefly made up of diabase and gabbro and their metamorphic derivatives, chloritic, epidotic and talc schists, and serpentine. This belt is isolated in the midst of granitic and gneissoid rocks belonging to the Laurentian, which constitutes the greater part of the peninsula of Labrador.

The diabases which are so largely distributed in this region are not exclusively those of the Huronian period, as will be seen later. In some places these diabases are invaded by veins of acidic rocks, probably of the Laurentian period. Thus about nine miles to the north of Lake Assinibastats, on the right bank of the river Chibogomou, a dyke of quartz porphyry, evidently related to the hornblende granites of Lake Assinibastats, cuts the schistose diabase.

Mr. Low, in his geological report of 1905, gives a probable classification of the rocks of this region which cover three epochs:—

Keewatin.—This is represented by portions of the diabase of this region of which one cannot state that they belong more to the Huronian than to the Keewatin. The existence of underlying Keewatin is shown by the presence of pebbles of schistose diabase in the lower Huronian conglomerates, which must have been derived from the rocks of the Keewatin by later erosion and have become included along with the granitic pebbles in a volcanic sheet, contemporaneous with the Lower Huronian.

Laurentian.—This includes some gneisses to the south of Lake Chibogomou and the hornblende granites of Lakes Assinibastats and Simon. These are the rocks that furnish the granitic pebbles found in the Huronian conglomerates as well as the constituents of the arkose in the Huronian.

Lower Huronian.—This is the most largely represented series. With the exception of arkose which is found in small quantity, the rocks of this series present a common character, namely a high percentage of magnesian[1] products. Although erosion and sedimentation took place during this period, as is shown by the rolled pebbles of the conglomerates, no purely sedimentary rocks have been discovered. These conglomerates themselves show, on examination under the microscope by polarized light, that they are of undoubted volcanic origin. Certain carbonaceous schists, found at the outlet of Lake Bourbeau, appear certainly to be of sedimentary origin, but they can be explained equally well as volcanic muds which have been impregnated with carburetted hydrogen. This has given carbonaceous matter to the schists.

In fact, either by metamorphism of the sedimentary rocks or by crystallization of the igneous magmas, properly so-called, the

Huronian rocks of Lake Chibogomou form a series with a clearly eruptive aspect and with a character decidedly basic.

It is difficult to classify the rocks according to the periods of the eruptions. Every new occurrence convulsed and broke the previously consolidated rocks; and for this reason one sees the diabase of Lake Doré becoming more and more folded as one approaches the gabbro. It is to these effects of folding and of dislocation that we must attribute the almost general alteration of the diabase of that region, which by the circulation of vapours and of water in the fissures have been transformed into schistose diabase, chloritic schists, talcose schists, and diabase rich in epidote and zoisite.

The gabbro forms considerable massives (Mount Sorcier, the shores of the central part of Lake Doré). One finds it again twelve miles to the north of Lake Assinibastats, in the hills rising above the right bank of the river Chibogomou. It appears as if the deposits of copper pyrites, discovered by Mr. Peter Mackenzie and Captain Machin, in Portage island and on the shores of Lake Doré, were formed at the contact of the gabbro with the folded diabase.

Serpentine is found nearly everywhere in this region. It forms sometimes considerable masses, as in Mackenzie bay, sometimes islands of small size, corresponding to the most highly magnesian portions of the primitive rocks. Every degree of transformation is to be met with from a diabase showing the presence of serpentine and talc, to a compact serpentine; then too one must be very cautious and not be sure of the presence of a serpentine mass containing asbestos, because one has discovered a green rock with an appearance of serpentine having in its broken or folded structures small quantities of fibrous material.

Compared with the serpentines of the Thetford region, those of the Chibogomou are less pure. Their colour is a very dark green, sometimes blackish, and they are somewhat friable. In the microscope one can see that grains of serpentine are surrounded, not only with bands of talc, but also with particles of magnetite.

Certain varieties of the serpentine, notably those of Mackenzie bay, are largely charged with magnetite, and to such an extent that the fractured surfaces of the rock instead of being filled with picrolite or with asbestos, as is generally the case, show solid magnetite.

Rocks containing Magnetite.—In the whole district bordering on Mackenzie bay, and in that to the north of the Bay of Islands, it is impossible to make use of the compass. The first point where these magnetic disturbances occur forms what is called the magnetic cone on the west shore of Mackenzie bay. Other similar centres exist, specially in Sorcier mountain and in Portage island, and one might say that all the rocks bordering Mackenzie bay and those of the Sorcier are magnetite-bearing rocks showing every degree between true serpentine and a diabase containing 60 to 65 per cent. of magnetite. A sample taken from a rock, the prospectors thought was serpentine, and in which asbestos had been looked for, gave on analysis the following:—

SiO_2	28.26
Fe_3O_4	34.38
MgO	26.20
Al_2O_3	9.07
Not determined (alkalies water)	2.09
	100.00

The particles of magnetite are primary constituents of the original rock; the concentrations which appear under the form of veins are all local and have been produced by a filling up *in situ* of the fissures opened in the rock either by contraction or other causes. This consideration raises the presumption that the veins of magnetite are not likely to continue to any depth, and that they are not in any way similar to true vein deposits in the large fractures of the earth crust.

Mineral Deposits.—With the present knowledge of the discoveries they may be placed in three classes:—

(1). Deposits of cupriferous and auriferous sulphides.
(2). Deposits of magnetic iron.
(3). And deposits of asbestos.

1. *Deposits of Cupriferous and Auriferous Sulphide.*—These are present in two different forms:

(*a*) *Deposits of Impregnation and of Segregation.*—In these beds the ore is found in nodules, in small veins, or in pockets, in a rock generally distorted and folded. Their origin should be sought for through the impregnation of the rock by sulphurous metallic vapours.

In the folded diabase of Lake Doré the richness of the metallic infiltration increases as one approaches the gabbros of the south; one is led to believe that these mineralizing vapours accompanied the intrusion of the gabbros.

In some places masses, not very important, of iron pyrites, of copper pyrites and of pyrrhotite, occur. Nowhere have I been able to find masses of sulphide exceeding two feet in greatest dimension. On the other hand the rock itself is strongly impregnated with sulphide and constitutes in itself an ore.

The chief prospects are the following:—

At Copper Point, on Portage Island two pits of 15 feet and 25 feet in length and of 4 feet in depth were made in a conglomerate having a magnesian cement. Iron pyrites, copper pyrites, pyrrhotite, siderite, and calcite were found in the rock. A concentration easily made by hand, resulted in the extraction of an ore containing 60 to 70 per cent. of sulphide. Two separate assays were made and gave on analysis the following:—

	No. 1	No. 2
Copper	1.33%	1.35%
Gold	$0.96	$0.20

A sample from a sulphide mass only gave some traces of gold and 2.69% of copper.

On the west shore of Lake Doré three small shafts were sunk in a gabbro containing quartz in parallel veins, which at a distance looked like gneiss. This gabbro contained inclusions of talc schist from the wall, rock which were caught in at the time of the eruption of the gabbro itself. Four or five tons of ore were to be seen; this had been selected by hand crushing of the rock taken from the shafts. One sample chosen from among those richest in sulphur gave the following:—

Copper	5.46%
Silver	$1.15 (at 0.50 per oz.)
Gold	$2.80

On the east shore of Lake Doré some half dozen small shafts were sunk, either in the talc schists, containing a little serpentine,

or in the magnesian rocks which are gneissoid in appearance. The ore is composed of sulphides and of carbonates of iron and of magnesia in great abundance. One of the shafts struck a vein of carbonate of copper, which is merely a filling up of a series of fissures in foliated schist.

Picked specimens taken from these gave the following assays:

Silver	$0.04	$0.02	traces
Gold	$0.20	$0.80	$2.60
Copper	1.17%	7.35%	3.37%
Nickel.	0.00	not determined	

Further prospects at other points demonstrate the existence of beds of sulphide of similar nature. It may be said that the whole of Portage Island and the north shore of Lake Doré consist of rocks impregnated by sulphides and that they are everywhere slightly auriferous. Crushing and washing of the rusty portions found on the surfaces of the schists nearly always yields some colours of gold.

(*b*) *Vein Deposits.*—The most important and the most highly developed is that which is called the Great Vein of Portage Island. This body is in reality a group of veins of quartz interstratified in the schistose diabase, the general direction of which is east to west. A secondary group, much less important, breaks off from the first in a direction S.W. to N.E., and constitutes the Little Vein. The Great Vein has been traced by nine open cuts running about N. to S., the longest of which extends for 102 feet. In the centre, where the veins attain their greatest breadth a shaft 45′ deep has been made. These operations have shown that there is a series of quartz veins interlaminated with the folded diabase. The greatest breadth of the body at the level of the shaft is 90′, of which 62′ are composed of solid quartz. This has been followed for about 900′. The parts richest in sulphur and in gold are found just at the shaft, the extremities at east and west are nearly barren.

Analyses have been made of specimens taken all along the cuts. The mean of numerous assays made by Mr. Hardman, after a visit to the spot in the spring of 1905, yields a percentage of free gold of $2.50 per ton. Some sampling which I did myself along the course of the cuts B and A gave the following:—

Cut A.

Silver	traces
Gold	$0.80
Copper	2.68%

Cut B.

Silver	traces
Gold	$2.00
Copper	1.28%

The oxydized debris behind shaft A gave the following:—

Silver	$ 0.40
Gold	$12.77

A series of samples made by knocking off a piece of the inner wall of the shaft every square foot, gave percentages varying from $0.15 to $2.00. One sample gave no result.

Some samples, chosen it is true from the most mineralized portions of the Little Vein, gave the following:—

Sample of Sulphide—	Silver	$ 0.35
	Gold	$ 3.00
Sample of Gossan—	Silver	traces
	Gold	$12.80

Two facts should be noted: (1) the variation in the percentage of gold in the different samples. This is caused by the fact that the gold is for the most part in a free state. For this reason in no case can analyses made by fusion with small quantities of material ($\frac{1}{2}$ oz. to 1 oz.) give uniform and certain results. A small stamp mill alone, used to carry out the amalgamation, can give any exact idea of the value of the beds. (2) The richer percentage of gold found in the oxydized portions as compared with that found in the sulphides. Therefore, after the removal of the upper portions of the lode, a diminution in the percentage of precious metals must be counted on.

Other veins of quartz have been discovered in the district of the Chibogomou. Among these an outcrop of quartz 75′ in breadth on the largest island in Lake Doré, and an outcrop of quartz on the south shore of Lake Bourbeau. The percentage of gold in the samples taken was insignificant. Two surface outcrops of auriferous quartz were discovered during my trip,

one on a little island on Lake Doré, the other at the inlet of Lake Simon. These veins of quartz are associated with calcite and with siderite. Samples taken from the rustiest parts have given:

Island in Lake Doré—Gold.	$16.40
Narrows of Lake Simon—Gold.	$ 5.00

2. *Beds of Magnetic Iron.*—These were first looked for around the magnetic hill in the west part of Mackenzie Bay; but it is now known that the rock which forms this hill is of impure serpentine which contains only 10 to 20 per cent. of magnetite.

The attention of the prospectors was then given to the veins of solid magnetite met with in Sorcier mountain, and on the north shore of the Bay of Islands. But nowhere have those veins a sufficient thickness or continuity; they only, as I have stated above, fill the shrinkage fissures in the serpentine.

These veins possess no interest from an economic point of view, except where, in certain places, the rock which contains them yields a considerable percentage of magnetite. This is the case on the east shore of the bay situated in III 8, Canton Roy, where one may for about 500′ follow along a natural cliff formed by the denudation of the rock and trace a vein of magnetite. This cliff is crossed in all directions by little veins of pure magnetite, varying in thickness from several lines to about 4 inches, and the rock itself, which forms the cliff, contains a considerable quantity of iron. The analysis of the rock gives as follows:—

SiO_2.	15.23
Al_2O_3.	1.09
Fe_3O_4.	63.07(Metallic Iron=45.7)
CaO.	traces.
MgO.	16.79
T_1O_2.	0.52
Sulphur.	0.40
Not determined (water & alkalis)	2.90
	100.00

According to this percentage, the rock itself forms an iron ore. In order to ascertain that there is really a bed of economically valuable iron, two factors must be considered:

(1) That development, accompanied by borings, shall demonstrate the existence of large masses with a similar percentage of iron.

(2) That the smelting operations carried out in a blast furnace shall prove that this ore may be smelted without a too large expenditure of fuel and of fluxes. Magnetic ores are in general very refractory and cannot be made use of when they are difficult to smelt unless they contain a large percentage of iron.

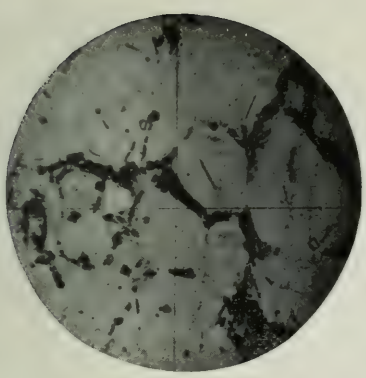
Deposits of Asbestos.—Numerous attempts have been made to discover asbestos, for nearly everywhere in the serpentine are to be found small quantities of fibrous matter in the fissures. Except on the asbestos island, situated in the west part of Mackenzie Bay, the prospectors have nowhere shown the existence of asbestos in marketable quantities.

Asbestos island in its central portion consists of a green serpentine, impure and highly magnetic. Veins of a purer serpentine and lighter in colour accompanied by veins of garnetiferous pyroxene are found on an elevation on the highest part of the island. It is at this level, in close proximity to the veins of pyroxene, that the finest asbestos on the island is to be found. Certain pieces of serpentine in close contact with the pyroxene rock contain a high percentage of silky asbestos in little parallel veins. Unfortunately this proportion of asbestos diminishes very rapidly with increased distance from the contact.

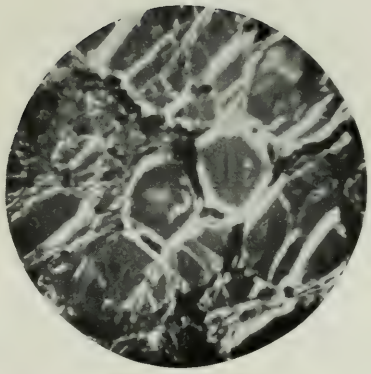
Open cuts were made on the south slope of the island into the impure serpentine. At the time of my visit the cuts shewed only a few thin veins of asbestos, as well as veins of picrolite (hard asbestos). On the dump, however, I could see blocks of serpentine thrown out during former operations, among which were fragments showing some fine veins of half to three quarters of an inch in width.

Conclusions.—On the whole this investigation shows that there do not exist anywhere, as was believed at the first, deposits giving a high percentage of the precious metals or of copper. Nowhere have I found cobalt bloom or smaltite carrying silver.

(1). With regard to the quartz veins of Portage Island, seeing that the highest percentages have been found in the oxidized portions, it is to be feared that the percentage will diminish in the



1*a*

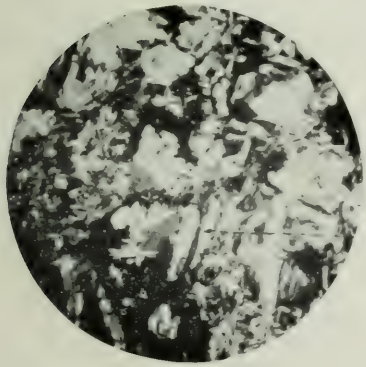


1*b*

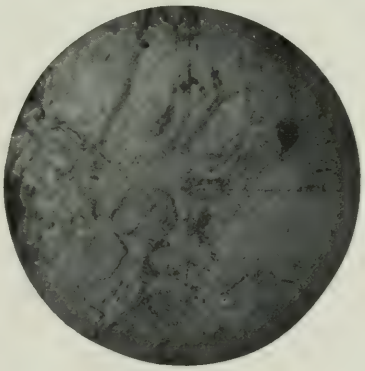
Serpentine from the right bank of the river Chibogomou (lot 8, range VI, Mackenzie).

1*a*. *By natural light* the wavy lines are grains of magnetite arranged round the large grains of colourless serpentine, which form the grey mass of the section.

1*b*. *By polarized light* the grains of serpentine appear grey black in colour. They are bordered by white bands of talc. The magnetite appears deep black in colour.



2*a*

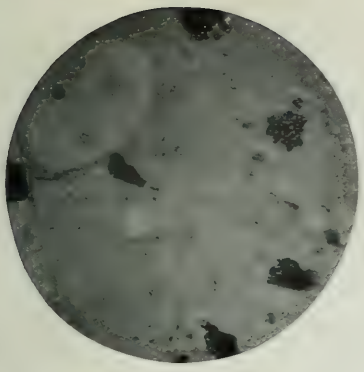


2*b*

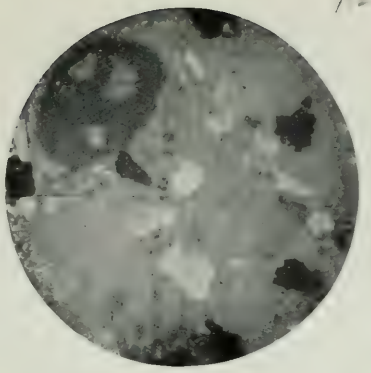
Another serpentine from the same district.

2*a*. *By natural light* to the right of the section filaments of magnetite are again seen surrounding the grains of serpentine and crystalline dolomite.

2*b*. *By polarized light* the white crystals are dolomite, the grey is serpentine. The banded material is talc; the grain *b*, surrounded by magnetite, is composed both of dolomite and of serpentine.



3*a*



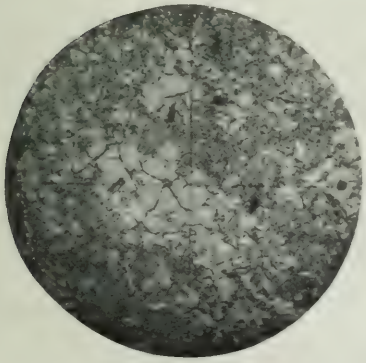
3*b*

Quartz Porphyry from dyke on the river Chibogomou.

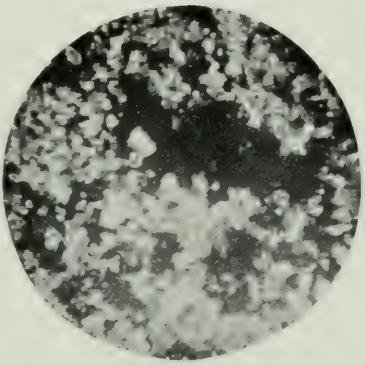
3*a*. *By natural light* in the grey ground mass of the section which is composed of small crystals of quartz, the black specks which appear are iron pyrites.

3*b*. *By polarized light* the white specks are of feldspar.

The oval patch at top and to right, appearing light grey by natural light and black by polarized light, is a large crystal of quartz.



4*a*

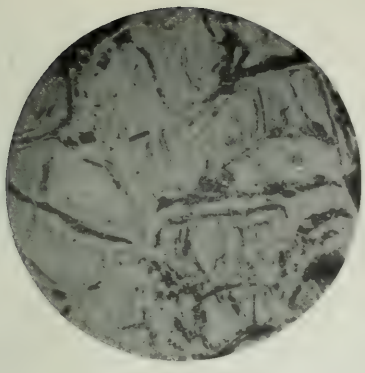


4*b*

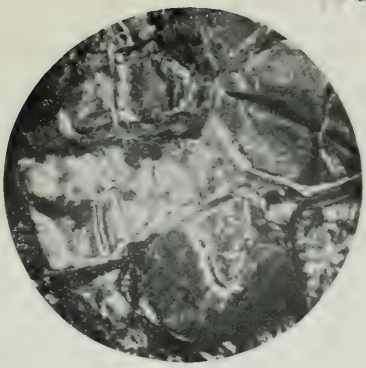
From the Pyroxene and Garnetiferous intrusion on Asbestos Island.

4*a*. *By natural light* the large individuals traversed by irregular cracks are garnet. The dark grey mass is composed of crystals of pyroxene and olivine.

4*b*. *By polarized light* the garnets appear black, the crystals of pyroxene and olivine range from white to black according to their position.



5*a*

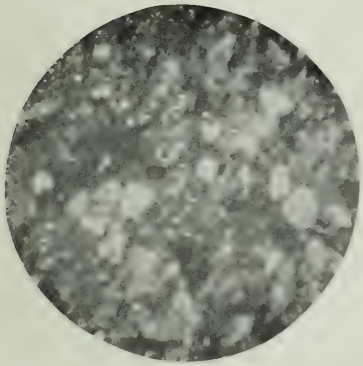


5*b*

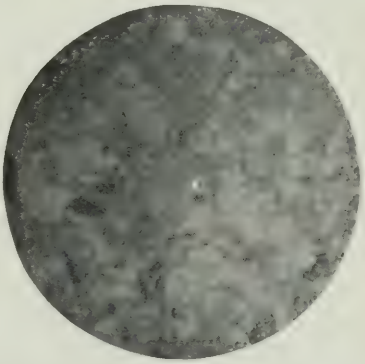
Serpentine from Asbestos Island.

5*a*. *By natural light* the black threads surrounding the grey serpentine are of magnetite.

5*b*. *By polarized light* the light bands surrounding the serpentine are of talc.



6*a*



6*b*

Specimen of Conglomerate (Straits of Mackenzie Bay).

6*a*. The white crystals are feldspar, which is decomposed, and of calcite or of dolomite; the black portions are of limonite.

6*b*. The grey ground mass is composed of chlorite.

lower sulphides, along with the diminution of the gold directly amalgamable.

(2). The segregation deposits in certain spots yield a good auriferous copper ore, after crushing by hand on the floor of the mine. It was impossible during the short visit I paid to the scene of the operations to make any sort of estimate of the tonnage. It is to be noted that the analyses given above correspond to the samples selected.

(3). Up to this date asbestos is not found in marketable quantities, except on the asbestos island in Mackenzie bay.

(4). Certain serpentine rocks having a high percentage of magnetite would form an important reserve of iron ore, if smelting experiments shall prove that this ore may be smelted economically in the blast furnace.

As regards the possibility of uniting the Chibogomou district to Roberval by a line of railway, it is difficult to give definite conclusions on account of the short time our expedition lasted, and from the fact that we never left the canoe route.

Such a railway is certainly desirable. Numerous prospecting expeditions have been made, considerable sums have been spent to develop this region, and some of these operations have shown the existence of deposits capable of a fruitful exploitation. It is to be hoped that these efforts will be recompensed. Only by the construction of a railway line, however, can the properties become profitably productive.

Such a railway would without doubt very quickly open up some centres of colonization, especially the whole of that very fertile district which stretches from Roberval to the foot of the rapids of Piemonka, and that of the delta of the river Nikobau. Large supplies of pulp wood and of hard wood are to be found, especially in the neighbourhood of the lakes Nikoban, Whitefish, and Obatogoman, and round lakes Doré and Bourbeau. Such a railway would also bring into service the water powers, such as the falls of the Vermillon, and of Gras and of the Chaudiere (100,000 horse power).

The accompanying micro-photographs show thin sections of the rocks from the region of the Chibogomou examined both by natural light and by polarized light with crossed nicols.

THE DEPTH OF ASBESTOS DEPOSITS.

By FRITZ CIRKEL, Montreal.

(Annual Meeting, Montreal, 1909.)

"Asbestos found at a depth of 400 feet!" This is the latest important news from the famous asbestos district—the Eastern Townships of the Province of Quebec. This intelligence is significant by virtue of the fact that the deepest present asbestos mine workings are but 200 feet deep. The discovery of asbestos at this greater depth was made under the following circumstances:

When the Black Lake Chrome and Asbestos Co. near Black Lake had completed the sinking of their shaft to a depth of 400 feet, which shaft had been sunk with a view to exploring their great chromic iron ore body, they ran in a drift passing through a deposit of chromite and serpentine and finally struck a series of "asbestos" veins of from $\frac{1}{4}$ to $\frac{1}{2}$ inch thickness, the asbestos being of great silkiness and flexibility. This "strike" would not, however, be of great general interest, except for its bearing on the important economic question in connection with the depth of asbestos deposits.

Before entering into a discussion on this subject, it should be stated at the outset, that the question of the permanence and persistency of asbestos deposits is a delicate one. It is a question concerning which few geologists or engineers familiar with existing conditions have as yet ventured an opinion; but from an economic standpoint it is highly desirable that the question of continuity of the deposits should be given close attention, since the future of a district, which at present is the chief source of the world's supply of asbestos, depends more upon the depth of its deposits than on the opening of new mines; but if the writer expresses an opinion on this subject, based primarily on observations in the field, he does so more with a view to stimulate discussion, than to present new and extravagant theories. Now, to the miner familiar with classes of mining, other than the exploitation of asbestos deposits, it will appear strange that a district whose

history extends back for over 30 years, possesses no record of any kind regarding the character of these deposits below a depth of 200 feet; and as a matter of fact there is no visible evidence in any asbestos mine of the extension of the deposits below a depth of 225 feet; and it is not less remarkable that this new discovery should be made accidentally in a mine of another class. If, however, we consider the methods employed in the exploitation of asbestos mines and also the difficulty or rather impossibility of testing the occurrences by diamond drilling, by reason of the fibrous nature of the rock and mineral, it is at once apparent that this lack of knowledge is due to causes arising solely from the peculiar occurrence of the mineral.

To treat the subject under consideration from a practical standpoint, it will be necessary to consider the results so far obtained at the present known depths and ascertain what deductions, if any, can be made therefrom; in conjunction with this, reference should undoubtedly be made to the genesis and also to the structural geology of the deposits, as well as to the formations with which they are associated.

Before commencing operations, a company organized to mine asbestos, requires to consider such questions as the amount of mineral available, the cost of its extraction, the cost of refining, and the probable profits on operations. These are, of course, considerations common to mining in all its branches, irrespective of the character or class of the mineral occurrence. But in almost all other classes of mining, the methods of exploitation are in the majority of cases characterized by the preparation for stoping or winning of the mineral through shafts and drifts; and exploration by diamond drilling is frequently resorted to, to ascertain the value of the property, before any considerable expenditure is made in installing costly mining and milling plants. The examining engineer is thus enabled usually to form reasonably accurate conclusions from available data. But in asbestos mining the case is different. Here the extensive, but mostly low grade, ore bodies do not admit of underground working such as is generally employed in mines of other classes; and in the opinion of the writer, only in the richer asbestos mines can the method of underground mining as inaugurated at Thetford by Mr. George Smith, the general manager of the Bell Asbestos Co., be followed.

The usual practice is to start quarrying on a promising spot and this quarry is gradually widened and deepened as work progresses. In the majority of cases, however, the claims, or undeveloped properties in the district, have nothing more to show than surface outcrops, and only occasionally have pits been opened to depths of (say) from 15 to 20 feet, to thus afford some grounds on which to base an estimate of probable value.

The enquiry may then suggest itself: "Why not then open up these prospects by sinking shafts on the ore bodies?" The reply to such a query would be that: The very irregular character of asbestos shutes, both in lateral and vertical directions, does not admit of intelligent exploration by deep shafts; for example, if a shaft is started on what is considered an excellent surface showing, it may be expected that immediately beneath the surface a lean shute will be encountered; and if it be found that, by chance, this lean shute extends vertically for some distance, the conclusion to be drawn from these conditions would certainly be not favourable; whereas, if possibly, this shaft had been sunk not over (say) 25 feet away, the results might have been entirely favourable. A striking example of this is afforded by a shaft sunk by the Bell Asbestos Co. twelve years ago and carried down to a depth of 137 feet on the westerly part of this property. The ground penetrated did not pay to work and it was consequently concluded that that part of the property was of little value. How erroneous this conclusion was is now demonstrated by the excellent showings exposed throughout the great underground workings here; and the very portion of the property originally condemned has since proved to be, the writer ventures to state, by far the richest asbestos ground ever discovered in the district.

But in discussing the question of the depth of asbestos deposits the only data on which we may base conclusions are those available in respect of the development work as so far undertaken in the working mines of the Eastern Townships.

From these operations, we have learnt the following facts:

1.—That the asbestos occurs as "vein" or "slip" fibre in pay shutes, occurring irregularly in the serpentine, the high grade material alternating with the lean or with serpentine poor in asbestos.

Fig. 1.

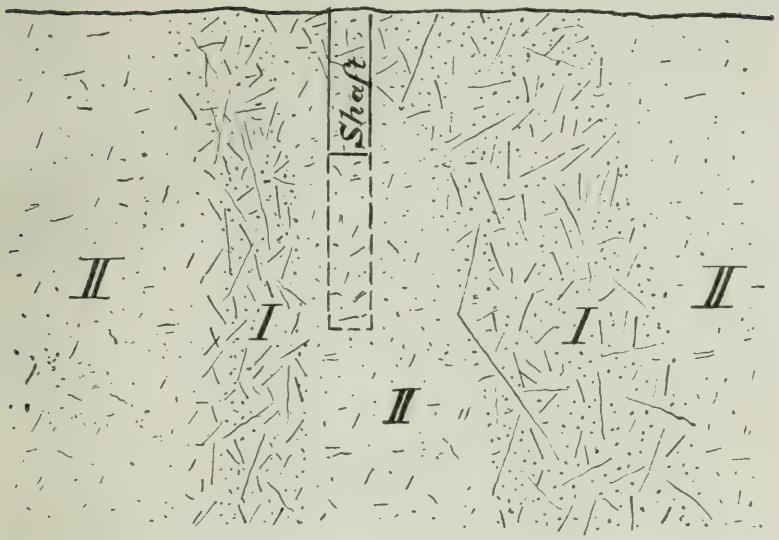
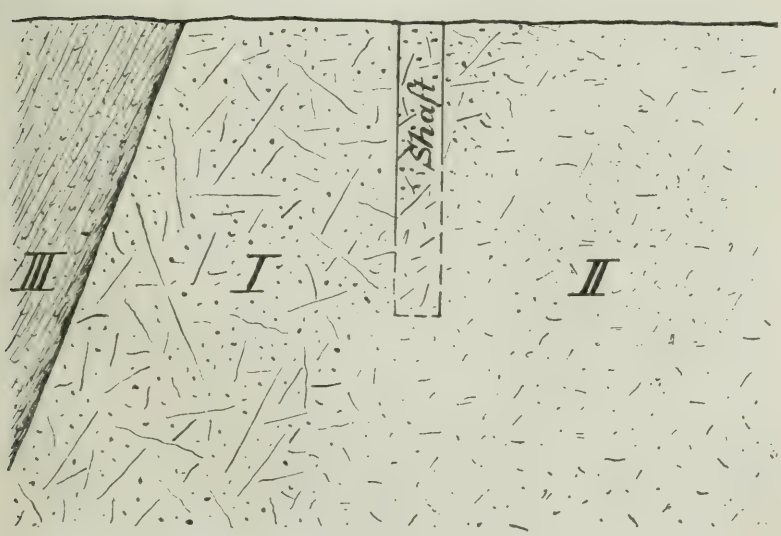


Fig. 2.



2.—That often rich pay shutes are encountered when approaching a granitic dyke or near the contact with the schist formation.

3.—That the quality of asbestos found at a depth of 200 feet, or, as in the case of the new discovery above referred to, at the greater depth of approximately 400 feet, the quality is the same, or nearly so, as that found on the surface.

4.—That wherever there is a *large* lateral extension of serpentine, and in the latter an asbestos pay chute, the lateral extension of which on the surface is more than 100 feet in both directions, this pay chute almost invariably, with occasional interruptions of lean serpentine, continues at depth.

5.—That exploration work by shafts, unless in connection therewith large roomy drifts are run, is entirely misleading, and in the majority of cases is of doubtful value as a means of developing a property.

Referring to the statement in regard to the lateral extension of the serpentine, it should be emphasized that this is an important factor in determining the continuity of the deposit, since small strips or lodes of serpentine are contaminated and interrupted in their continuity by trap-like portions of the adjacent country rock, which are never expected to be present in an extensive development of serpentine (except granitic intrusion) like that of Thetford and Black Lake. As experience has shown, this interruption in the narrow serpentine lodes may take the form sometimes of permanent displacements and may cut off at increased depth an asbestos deposit, which, on the surface, showed all the usual characteristics of a pay chute.

The serpentine belt which stretches from Range III, Broughton, with a few "surface" interruptions, directly through the townships of Broughton and Thetford-Black Lake area, affords great opportunities and scope for the study of the question of the permanence of the asbestos deposits, and the following facts are herewith submitted:—

At the "Quebec" mine the fibrous rock, found on the surface in small shallow pits, continued both in a lateral and vertical direction along the contact with the schist formation, and the rock is now mined in a quarry about 300 feet long, 125 feet wide and 65 feet deep. At the Broughton property the fibrous serpentine

which appears only in a few places on the surface, was found to extend all along the contact, and the quarries are now 85 feet deep. In both cases the fissured and fibrous condition as observed on the surface was found to continue as depth was attained and although there may, perhaps, be an occasional change in the quantity of the vein fibre—as in the case of the "Broughton"—this does not in any way influence the general conditions in regard to the occurrence at depth in these places.

The great quarries of the "King Bros.," "Bell," "Johnson," and "Beaver" at Thetford, and of also the deep quarries of the "British Canadian," show conclusively that, with depth, no marked change in the quality or richness of the asbestos chutes takes place; indeed, at a depth of 300 feet they appear as continuous and as rich as at any time in the history of these mines; while the new discovery of asbestos at a depth of 400 feet in the shaft of the Black Lake Chrome & Asbestos Co. leads to the conclusion that asbestos deposits are not shallow in their occurrence.

The study of the geological conditions of the district has now fairly well established the fact that the serpentine of the Eastern Townships, the mother rock of chrysotile asbestos, is a secondary rock; it is the alteration product of olivine-diorite—a rock of igneous origin. It can be conclusively shown that in nearly all cases this anhydrous olivine rock was changed gradually into serpentine or a hydrous silicate of magnesia, and that subsequently through the action of certain agencies, fissures were formed and filled with an asbestos bearing solution, which gave rise to the ultimate crystallization of the fibre.

For the purpose of a better conception of these physical and chemical changes and their bearing upon the persistency of the deposits it will be necessary to state briefly how they were probably occasioned.

Sterry Hunt* shows that the alteration of olivine into serpentine would result in an increase of volume amounting to over 30 per cent. Admitting that some of the silica or even of the material is lost in the process of hydration, there must be still a great expansion at some time of the mass, and this expansion must at the same time mean increased pressure in the interior of the rock, since the surrounding formation undoubtedly did not

* Mineral Physiology and Physiography, p. 506.

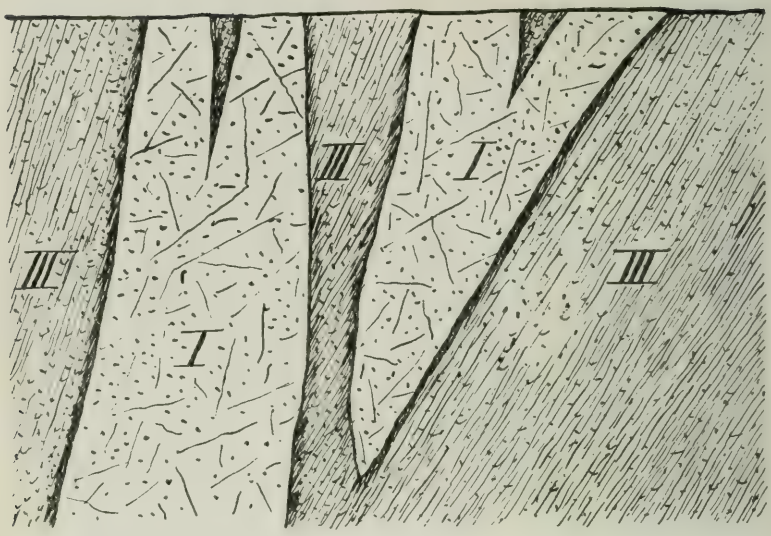


Fig. 3.

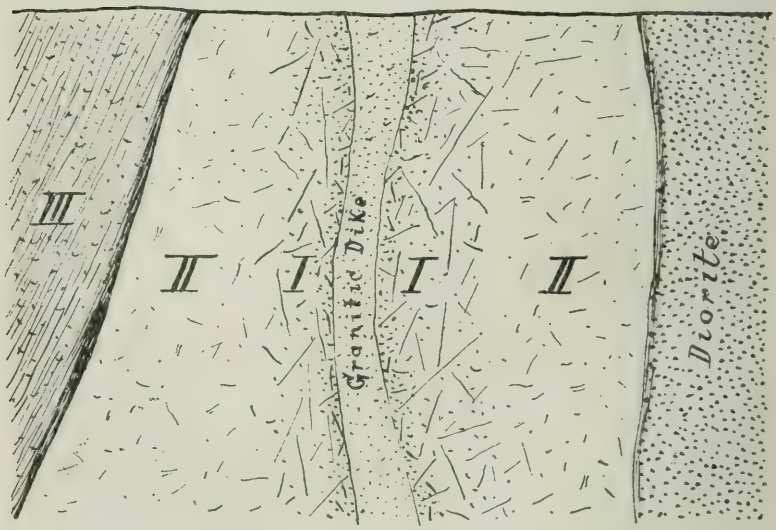


Fig. 4.

allow of an easy expanse through increase in volume. It was thus impossible that fissures could have been formed at this stage of the process.

There seems to be no question that as soon as the process of alteration was finished, a readjustment in the rock masses took place and this readjustment resulted in the formation of joints and slickensides, such as we find in the mines to-day and *not* as is generally supposed in the formation of fissures. This theory is substantiated by the fact that in the mines at Thetford numerous places can be seen where these fissures (asbestos veins) cross directly through joints and slickensides. The next question is, how have these fissures been formed? Was it through shrinkage due to a loss in silica or due to shrinkage of the rock mass through cooling? Now, if these fissures were formed through the loss of silica, they would have been formed during the process of alteration, that is before the joints and slickensides were formed, but the impossibility of this is shown above.

The most rational explanation, and the one which seems to gain most support, is that the formation of cracks was caused by cooling and shrinkage of the rock masses similar to the formation of cracks through shrinkage of a gelatinous mass of iron carbonate in the so called septarian nodules of clay iron stone, as suggested by Merrill. However, it is also probable that the intrusion of those granitic dikes, so frequently met with in the serpentine masses, has caused or facilitated to a great extent the formation of numerous fissures in the immediate proximity of these intrusions by rapid dehydration through the agency of heat. The fact that very frequently an accumulation of asbestos veins can be noticed when approaching these intrusive dikes seems to substantiate this theory.

Now it is obvious from a geological point of view that all these radical changes, which were perhaps brought about during long geological intervals, took place not only on or near the surface but were also deep seated; it is impossible to imagine that the changes in the character of the rock, viz.: the alteration into serpentine, the subsequent readjustment of the rock, the forming of fissures and the ultimate filling of the latter with a crystallization of the serpentine solution, should have been confined only to rock portions near the surface; hence we are justified in assuming that

these changes must have affected the whole system; that is, they must have extended to great depth; for we cannot conceive of any influence coming from the surface or being exerted near the latter which could have created such conditions.

There exists a great difference in the quality of serpentine and the fibre found in the Thetford and in the Broughton district and much interest is being manifested at present in the question as to the relation, if any, between the two occurrences. Recent investigations have shown—and this is amply supported by the discoveries which have been made during the last year or two—that the Broughton serpentine belt, which occupies a straight, narrow strip in the Broughton township and in the easterly part of Thetford and conformably deposited with the Cambrian schists, continues with few small interruptions into the great serpentine knoll in the vicinity of Thetford village, and that further a gradual change can be noticed in the "slip fibre" quality of the asbestos found at Broughton to the vein fibre quality as found in the westerly part of Thetford.

This evidently goes to show that there exists a genetic relationship between the two occurrences and it seems very probable indeed, that the serpentine belt throughout its extent has its origin in one common source; but that at Broughton, where the "slip" asbestos fibre is produced, additional changes and readjustments have brought about the prevailing conditions. In order to make this clearer a first attempt has been made by the writer to tabulate the successive changes which the original rock in all probability underwent.

1.—Intrusion of olivine-diorite through the earth crust from below.
2.—Gradual alteration of the rock to serpentine through hydration, and perhaps loss of silica, increase in volume.
3.—Slow readjustment of the rock masses, resulting in the formation of joints and slickensides.
4.—Subsequent formation of fissures as receptacles of asbestos fibre, through shrinkage of the rock and also through injection of granitic dikes.
5.—Infiltration of serpentinous solution from the sides of the wall through process of segregation and subsequent slow crystallization of chrysotile.

6.—Second slow readjustment of the magmatic rock mass and formation of "slip" fibre.

The writer has gone more fully into the question of origin than he at first intended; but this was deemed necessary in order to follow step by step the alteration and successive changes of the original rock mass and also to show that these most radical changes must have affected the serpentine not only near the surface but also to a considerable depth.

To what depth then these rock masses have been affected by all these changes to produce what is now known as asbestos rock must remain a matter of surmise, but—judging from the results which lie now before our eyes—I venture the opinion that these workable asbestos deposits extend to considerable depth, probably to several thousand feet.

DISCUSSION.

MR. J. A. DRESSER:—The question of the depth of asbestos deposits in the Eastern Townships depends in a large degree for its solution on the form taken by the eruptive rock from which the serpentine has been derived. This has not yet been satisfactorily determined. The form may have been a sheet or laccolith, intruded between beds of older rock. In that case the sheet would be more or less nearly horizontal in position, and would not have reached the surface until it was uncovered by the erosion of the overlying beds.

Or it may have been an intrusive mass of rock—which was brought to the surface and has since had its upper portions removed by erosion.

In the former case the depth of the asbestos would necessarily be limited by the thickness of the intruded sheet, but in the latter case the serpentine, and consequently the asbestos, might continue to an indefinite depth.

The other factors necessary to the occurrence of asbestos are the segregation of olivine in the original rock, and the alteration of

the olivine to serpentine. Of the first it may be said that olivine is a mineral characteristic of the lowest known depths of the earth's crust; and of the second that serpentinization is a deep-seated process, which, unlike weathering, does not depend on the action of the atmosphere to produce it.

Therefore, except for the possibility of reaching the floor of a sheet, it seems safe to conclude that the asbestos deposits of the Eastern Townships will continue for as great a depth as they can be profitably mined.

In discussing the rocks of the asbestos deposits there is often much unnecessary confusion of terms. It should be borne in mind that olivine is a mineral, not a rock, and so has a definite composition. The rocks in which it occurs vary as to the likelihood of their containing asbestos according to the proportion of olivine they contain. The principal varieties that may be distinguished in the field are pyroxenite, consisting of pyroxene of one or more varieties; peridotite, consisting of olivine pyroxene, and sometimes secondary hornblende, the olivine preponderating; and an extreme basic phase of peridotite, called dunite, which consists of olivine with a little chromite. It is by the alteration of this alone that the rich asbestos ground is formed. The term diorite cannot be correctly applied to any of the rocks of this district.

GRAPHITE CONCENTRATION.

By H. P. H. Brumell, Buckingham, Que.

(Annual Meeting, Montreal, 1909.)

Apparently simple, the solution of the problem of the concentration of the graphite contents of disseminated ore has proved extremely difficult, and it is only after many years of assiduous endeavour that the present modicum of success has been attained. As early as 1860 efforts were made to market Canadian graphite, and in 1867 the first mill for the dressing of the ore of Labelle County was begun in the Township of Buckingham. Since this initial effort, however, several mills have been erected, each, in succession, embodying some new feature and showing a gradual advancement from the early and crude method of buddling to a system of dry separation, now conceded to be the only logical method of treating so fugacious a mineral as graphite.

In the following brief resumé of the work done in Canada, reference is made only to that ore so abundantly found in the County of Labelle, in the Province of Quebec, and sparingly in the counties of Renfrew and Lanark, in Ontario. This ore is essentially a graphitic schist or gneiss carrying the graphite in more or less small lenticular particles and consists, in Labelle County, of quartz, feldspar (usually orthoclase) and hornblende, with smaller quantities of pyroxene, sillimanite and pyrite. The major portion of the gangue material is made up of quartz and feldspar, both having a specific gravity of about 2.5, while the gravity of Canadian crystalline graphite is 2.26, which leaves a very small margin on which to work. The remaining minerals are somewhat heavier, the specific gravity of hornblende being about 3, pyroxene 3.3 and sillimanite 3.2. Pyrite, with a gravity of about 5, is a negligible consideration, both on account of its greater weight and the usually very small percentage in the ore.

The earlier attempts at concentration were all made with stationary buddles of an uniform type, the vat being about 16

feet in diameter, with a depth of 3 feet, the floor having a slope of 3 inches from the centre post to the edge. After being crushed in ordinary jaw crushers, the ore was stamped wet and fed to the buddles, with a considerable stream of water, entering them through short pipes from a revolving pan fixed to the lower end of the shaft, to which, also, was attached two adjustable sweeps. These sweeps gave to the water and accompanying ore a gentle centrifugal motion, sufficient to carry away the lighter particles of graphite, which were deposited around the edge of the buddle, the heavier minerals being deposited near the centre, while the superfluous water escaped through a sluice gate at the side, control of which was effected by means of small swinging stops. When a buddle was filled it was allowed to drain and the material taken out by hand, the outer zone being of concentrates followed by a ring of seconds or middlings, the innermost portion consisting of tailings. These seconds were re-buddled a second and, sometimes, a third time. By the foregoing method a very coarse separation was made, the concentrates rarely assaying 60%, from a 10% ore. On drying, however, and passing the dried product over a series of screens, considerable quantities of the coarser sized flakes were obtained. Mills equipped in this way were erected and spasmodically operated at Oliver's Ferry in Ontario, and in Buckingham and Lochaber townships in Quebec, but were unsuccessful; the non-success, as proved by later development, being entirely due to the system of disintegration and concentration. The ore, while soft and lubricous, is a peculiarly tough one and difficult to stamp, the stamps at times working the crushed wet ore into the shape of a cylinder with smooth polished sides, in which the stamp moved freely and ineffectively. As to capacity, the best result obtained was about one ton per day per stamp (850 lbs.) and, as the buddles were emptied by hand, no practical mechanical means having been found, the entire process was found to be slow and much too costly. At several of the early mills keeves were used with but slight success. Experiments carried on at the mill of the North American Graphite Company in 1899 resulted in the replacing of the buddles by the so-called Brumell separator which, although a vast improvement on the buddles, soon gave way to pneumatic separators, the type first used being the Hooper concentrator. After the installation, at this mill, of the latter a

(Courtesy of Canadian Mining Journal)

FIG. 1—Buckingham Graphite Company's Mill, Buckingham, Que.

(Courtesy of Canadian Mining Journal)

FIG. 2—Part of Finishing Plant, Buckingham Graphite Company, Buckingham, Que.

fairly economical system was adopted and the ore was rolled dry. After crushing, the ore was dried in a revolving fuel dryer, after which it passed through two pair of rolls, the overs of a 20 cloth being returned, and the resultant material sized in revolving screens. The sized material was then treated on the Hooper tables, the concentrates going to the finishing plant, while the seconds went to the Brumell separators, the concentrates of which were then dried and sent with those from the Hoopers to be finished. The foregoing has been superseded at the mill of the Buckingham Graphite Company, by the adoption of a system of dry concentration throughout, involving the abolition of the Brumell concentrator. The ore, after crushing, drying and rolling is brought by an impact screen to a certain degree of fineness, after which it is sized in a dry ore sizer; certain sizes being treated on a new type of pneumatic concentrator, other sizes going to the Hooper tables, while the finer ones are treated on a barrel concentrator. This mill is believed to be the only one commercially producing graphite from disseminated ore. While concentration has been the chief difficulty, there is another important feature in the manufacture of graphite, viz.:—finishing and grading to suit the various trades using the mineral. In a graphite mill there are three distinct departments for crushing, concentrating and finishing. In the former every endeavour is made to bring the ore to a size wherein the particle is "freed" from its matrix without reducing its size; as in the markets a large sized flake commands a much higher price than the smaller ones, flakes coarser than 70 mesh being most in demand. This desirable condition is brought about, in a marked degree, by the use of rolls set in sequence of increasing pressure and the material scalped off as it is rolled to the desired mesh. In practice it has been found that a series of rolls bringing the ore to a maximum mesh of 20 gave the best results when, with proper care and manipulation, 80% of the material would be of a size between 20 and 80 mesh, 10% between 80 and 150, and 10% allowed to go to the waste dump as too fine for economical treatment. After concentration the treatment accorded the material is continued with millstones of various materials, and revolving flour mill screens. In this treatment, as in rolling, care is taken to reduce the size of particle as little as possible, the object being to grind and reduce

to a powder the associated foreign, and mainly silicious, materials, separation from which is effected by a system of scalping and the milling and screening is carried on until the residual material is a fine ground graphite, suitable for stove polish, foundry facings and paint, assaying from 25% to 75%. With the plant as installed at the Buckingham Graphite Company's mill, the ore, carrying about 12% of graphite, is concentrated up to from 75% to 86% according to size, and the concentrates, in turn, finished, the finished or marketable stocks assaying from 70% to 96.5%.

The following brief descriptions of the various plants in Ontario and Quebec, other than that of the Buckingham Graphite Company already described, embody all that the various owners have allowed to be known and are, in consequence, not strictly accurate as to detail.

THE BUCKINGHAM COMPANY.

This mill, which must not be confounded with that of the Buckingham Graphite Company, is situated on lot 26, range VI, township of Buckingham. The ore after a preliminary drying, was crushed and rolled with one Dodge crusher and one set of Krom rolls, after which it passed to screens and buhrstones. The entire product of the rolls, without any attempt at classification or concentration, was then run through buhrstones, reducing much of the gangue to a proper degree of fineness, after which it was run over silk bolting cloths, the graphite particles, which escaped the grinding operations, tailing over. This process was found to be so wasteful of the graphite contents of the ore that the business was closed down and the mill has now been idle for about ten years.

ANGLO-CANADIAN GRAPHITE SYNDICATE, LIMITED.

The works of this late company (formerly the North American Graphite Company) are situated on lot 28, range VI, township of Buckingham, about one mile to the north-west of the foregoing and were operated on a part dry and part wet principle. The ore was crushed, then dried in a revolving fuel dryer, passing thence to two pair of rolls, the overs of a 20 screen being returned

(Courtesy of Canadian Mining Journal)

Fig. 3—Diamond Graphite Company's Mill, Buckingham, Que.

(Courtesy of Canadian Mining Journal)

FIG. 6.—Globe Refining Company's Mill, Port Elmsley, Ont.

(Courtesy of Canadian Mining Journal)

FIG. 7—North American Graphite Company's Mill, Buckingham, Que.

and re-rolled. From the rolls the crushed ore passed to a battery of revolving screens, making four sizes which were then treated on Hooper concentrators, the middlings going to two Brumell separators, the concentrates from the latter being dried in a revolving steam dryer. The concentrates from both these sources were then finished with buhrstones and reels clothed with silk bolting cloths. These works were closed down about four years ago and have remained idle since.

THE DIAMOND GRAPHITE COMPANY.

This mill is located on lot 14, range X, township of Buckingham and is, at the time of writing, in process of reconstruction. The system first adopted was similar to that at the Buckingham Company's plant, no attempt at concentration being made. The ore, after drying, was crushed and rolled, going thence to flouring rolls instead of buhrstones, after which a system of screens was supposed to complete the operation. This method was found to be very wasteful and the management decided to replace the flouring rolls with Krom pneumatic jigs, and the change is now being made. No attempt at finishing the concentrates beyond screening is, apparently, contemplated.

THE BELL MINES.

This mill is situated on lot 2, range V, township of Buckingham, and is the only one in Canada employing a wet method throughout. The ore, after crushing, is reduced, with a heavy stream of water, in a Williams disintegrator to about 10 mesh, after which it is classified with wet screens and treated in Kendall separators. As far as is known no further treatment is accorded the concentrates.

The development of this mill, which is the newest in the district, is being watched with interest on account of the methods employed. Some of the concentrates obtained during the trying out of the plant were particularly good.

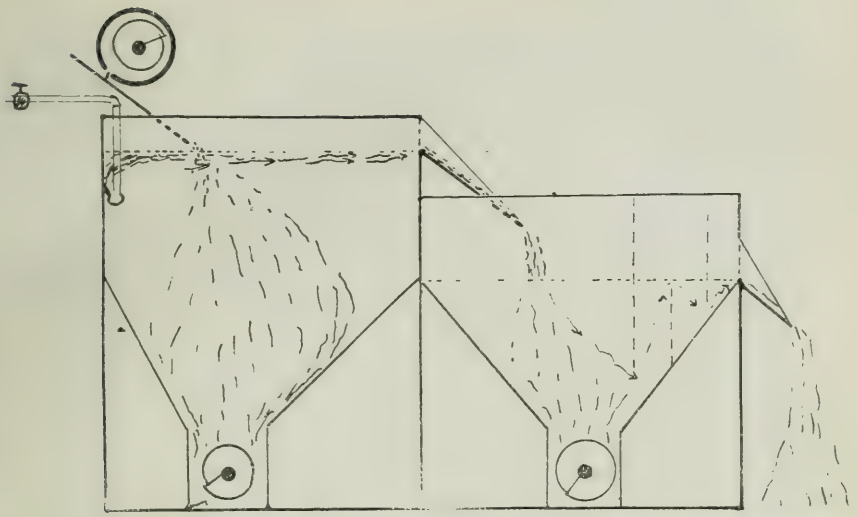
THE CALUMET GRAPHITE MINING AND MILLING COMPANY.

The works of this Company are located on lot 16, range II, township of Grenville. In this mill no attempt, apparently, was made at concentration, though but little is known of the methods employed. It is understood that no shipments of finished stock were made, the total production consisting of a quantity of ground ore, not sufficiently pure for even the lower uses to which graphite is put. The finished material referred to was the product of a pebble mill, installed for the avowed purpose, according to the monograph on "Graphite," published by the Mines Branch of the Department of Mines, of "cleaning and polishing of the graphite flakes." This method of "cleaning and polishing" would appear to have cleaned and polished the graphite to a vanishing point, as the resultant material was a grey, black-lustre powder consisting of ground limestone and associated minerals, and graphite, of no commercial value. This mill is not now in operation. Reference to the use of pebble mills will be made further on.

GLOBE REFINING COMPANY.

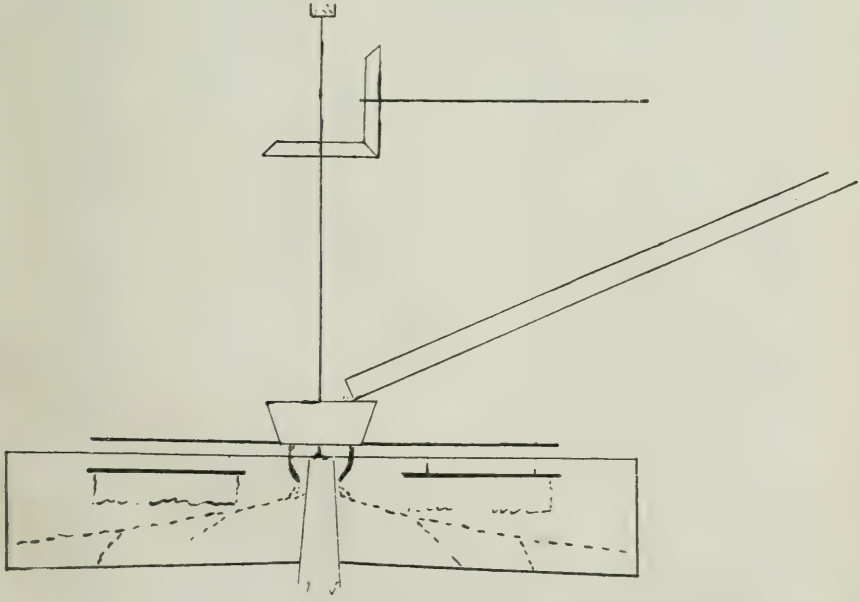
This mill, located at Port Elmsley, Lanark county, Ontario, was operated spasmodically until 1905, since when it is believed to have been idle. The ore, after crushing, was dried on a stationary sloping floor dryer and after being rolled was classified with revolving screens, from whence it went for treatment on Krom jigs after which it was milled on millstones and their accompanying screens. In practice the Krom jigs were not found to be satisfactory and in consequence taken out and the finished product made by flouring rolls and reels, similar to the process until lately prevailing at the Diamond Graphite Company's mill in Buckingham.

For the purpose of this paper it is not thought necessary to enter into descriptions of the various concentrating methods in vogue outside of Canada, except to say that in Germany and Austria, where the concentration of graphite is carried on to a very considerable extent, nearly all the mills operate on wet principles and in the United States on a combination of both wet and dry.



(Courtesy of Canadian Mining Journal)

FIG. 4—Brumell Separator.



(Courtesy of Canadian Mining Journal)

FIG. 5—Diagram of Buddle

In the following brief descriptions of the various concentrators and methods of graphite ore dressing in Canada it is not needful to enter into details as to the various types of crushers and rolls. The latter may be of any good type but should not be differential, while for the preliminary rough crushing all types of crushers have been used, the best service, in jaw crushers, being obtained with those of the Dodge type. On account, however, of the slippery character of the ore, particularly if it have a high graphite content, it has been found that better results were obtained when a rotary crusher was used, of which there are several types all equally suited to the work.

The following, in brief, are the various concentrators which have been, or are being, used in Canada.

WET SEPARATORS.

Buddles.—Already described.

Keeves.—Tubs, usually, of three or four feet in depth, by three feet in diameter with removable sweeps attached, at right angles, to a vertical shaft in the centre. The ore, usually fines, was fed, with a sufficiency of water, until the tub was filled, a strong centrifugal motion being imparted by the sweeps. When the charge was completed the sweeps were elevated and while the contents were settling the tub was knocked on the outside, the slight jarring effect keeping the lighter graphite in suspension longer than the heavier gangue minerals. The operation lasted about three hours, when the water was drained off and the sediments removed by hand. In a three foot keeve there was usually a deposition of about fifteen inches, the graphite, in a fair state of concentration, being found uppermost. This operation was slow and, requiring hand labour, was expensive and was never adopted to any great extent.

Brumell Separator.—This is a method, rather than a machine, and relies upon the floatability of graphite, when dry, upon, rather than beneath, the surface of water. The apparatus employed is a square wooden box, twenty feet in length by four feet wide and five feet deep, filled with water and with a surface current extending across its width, obtained by jets projected against the side at an upward angle of 45° and about nine inches below the

surface. This box is hoppered along the sides, the cants throwing the tailings into a worm conveyer which, in turn, conveys the refuse to an elevator with perforated buckets, the chain of which actuates the conveyer. The dried ore is fed to the surface near the side over the jets by means of a spiral steel conveyer enclosed in a tube with a longitudinal slot the entire length, and, passing over a glance board, is dropped about one half an inch in a thin curtain to the water. The graphite which remains floating is carried over into a settling tank, hoppered to the centre, where it is wetted, and drops through an opening into a spiral steel conveyer enclosed in a tube and inclined at an angle of 45°, from whence it is fed automatically to a revolving steam dryer. The water passes under and over several stops and eventually escapes through a screen at the opposite side. This apparatus, while very economical as to power and capacity and entirely automatic, is, at best, only a rough concentrator rarely bringing a 10% ore up to 65%, and in consequence is not now in use.

Kendall Separator.—This machine, patented in 1902, is the invention of Mr. C. Kendall and is now in use at the Bell mine in Buckingham township, where it is being practically tested. In principle it relies on the affinity of oil for graphite and consists of a vertical cylinder terminated at the base with an inverted cone. The ore is thoroughly mixed with a superabundance of water and before entering the separator is again mechanically mixed with a heavy gravity mineral oil. The whole, while in an agitated state, is fed down to near the base of the machine by an inner tube which extends to a height of about ten feet above the cylinder. The graphite, with its adhering particles of oil, rises to the surface and flows in a thin film over the edge of the cylinder to a launder, which carries the pulp off to a settling tank from whence the oil is syphoned to be used again. At the bottom of the cone is a swinging gate valve, which allows the water and tails to escape and acts, at the same time, as a regulator to the thin film of oil and graphite flowing over the lip of the cylinder. In principle this method is undoubtedly good but time alone will tell as to its practicability. Great difficulty will, no doubt, be encountered in keeping a regular height on the continuous charge in the cylinder and the problem of entirely ridding the graphite of the oil will, probably, be difficult to solve.

DRY SEPARATORS.

Labouglie Separator.—In 1876 a patent was issued to Joseph Labouglie, of Buckingham, which covered the adaptation of an ordinary fanning mill. The dried ore was dropped before the blast of a fan, similar to a grain winnowing fan, and the lighter graphite was supposed to be projected further than the heavier gangue minerals and receptacles were arranged at increasing distances for the collection of the various products. It is not necessary to say that the machine was never adopted and mention is only made here to illustrate the early date at which efforts were directed towards dry separation.

Nappenburg Separator.—This apparatus was installed at the mill later owned by the Buckingham company, but at the time of its installation was owned by Messrs. Pew and Weart. In principle it was similar to the separator just described but much more elaborate and consisted of a deep shaft or well about two feet by one foot with blasts arranged at various points directed horizontally from the wider side across to screens of various mesh. The dried ore was fed in a curtain from the top, dropping down in front of the blasts, which were supposed to project the lighter graphite across to and through the screens. These blasts were arranged in increasing strength from top to bottom and the various screens had spouts which were supposed to, but unfortunately never did, convey the concentrates to their respective bins, the finer smaller particles from the uppermost and the heaviest from those near the bottom of the shaft. Needless to say this method was not a success.

Krom Pneumatic Jig.—This was probably the first pneumatic machine to be used in Canada and has been found, while good in principle, to be somewhat too delicate in operation for practical work. It consists of a chest containing a swinging door blower giving rapid pulsations of air which is carried to tubes of silk bolting cloth arranged close together to form a bed whereon the concentration is made and as the continuous charge of ore is carried forward in strata a knife edge adjustable tail board is supposed to skim off the graphite, allowing the tails to drop under or behind. There are many details as to arrangement of feed and delivery of heads and tails which need not be gone into here.

With an uniform ore and an absolutely steady power the machine would, no doubt, be very satisfactory, but these are conditions difficult to obtain. The monograph on "Graphite," already referred to, thus naively refers to the machine:—"The apparatus, when carefully watched, works satisfactorily, but it has no power of self regulation. This causes the machine, if fed more rapidly than normal, to contaminate the concentrates, the flakes with the tailings, and if fed less rapidly to lose concentrates in the tailings. And, further, if the feed be regular in quantity but the percentage of graphite variable, then the rise in percentage will enrich the tailings and the fall in percentage will contaminate the heads."

Hooper Pneumatic Concentrator.—This machine consists of a flat chest containing a diaphragm actuated by eccentrics on a driven shaft running horizontally beneath the chest, and this chest, in turn, is surmounted with a movable deck of a peculiar design, the two separate parts being connected with a hollow ball and socket joint. The eccentrics, which are adjustable, act upon the diaphragm causing pulsations of air to pass up through the ball and socket joint and through a second diaphragm immediately below the deck which consists of a cast iron grating covered with broadcloth. Over this grating is the concentrating top, consisting of a cast iron frame with parallel strips of sheet brass extending diagonally from side to side, and these in turn are surmounted by another set of parallel strips diagonally in the other direction. The ball and socket joint permits of the top being set at any vertical or lateral inclination. The ore is fed to the upper end of the concentrating top and is aided in its travel to the lower end by the rapid pulsations of air which pass up through the broadcloth effecting at the same time a concentration according to gravity. The lower brass strips, or riffles, carry the heavier portions to the lower side of the deck while the upper brasses or channels carry the lighter or top stratum diagonally to the upper side. At the discharge end of the deck are finger pieces which guide the various products to their respective receptacles. These machines require very accurate sizing of material and when once set as to eccentric throw, speed and vertical and lateral inclination, require no further care beyond cleaning the broadcloth bed which should be done about every five hours.

Barrel Concentrator.—This machine has given excellent results as a rough concentrator and consists of a revolving cylinder set with a slight downward inclination and having straight narrow flanges extending throughout its length. The discharge end is open while the feed end fits, as snugly as possible, into a square stationary chest to the opposite side of which is connected the suction pipe of an ordinary exhaust fan. The ore is fed into the upper end of the cylinder and, by means of the flanges, is carried up and dropped across the exhaust draft in the cylinder, the inclination finally discharging the tails at the lower end. From the fan the concentrates are blown into a dust collector or bag house for further treatment. It is unnecessary to state that for this treatment it is essential that the ore be very carefully sized.

Someone has written somewhere that "separation without classification is damnation" and this certainly is the case where pneumatic concentrators of any type are used.

Flour mill rolls.—This treatment of graphite should not properly be classed as concentration as the operation consists merely in rolling with smooth rolls set with a slight differential. These rolls are in sets of either two, four or six and the object is, presumably, to crush to a dust the foreign material and to trust to luck that the particles of graphite slip through untouched. In practice it has been found that a very large proportion of the graphite was ground, as well as the gangue material, and that it was not possible to obtain a particularly high grade of graphite by this method.

Pebble or Tube Mills.—Probably the most erroneous idea prevalent among inexperienced graphite producers is that these mills can be used for the cleaning of graphite from the gangue and for the polishing of the graphite flakes. In the monograph on "Graphite," already referred to, appears the following very misleading statement:—"This mill on account of its great efficiency and smooth action has found its way into graphite mills of recent date; it is used for polishing and grinding graphite flakes and can be so adjusted that the latter are freed from sand; it replaces effectually the old buhrstone mill, while other mills either crush, twist or cut the material."

No more misleading statement could possibly have been made as these mills are used only for fine pulverization and are

usually equipped with an exhaust, with dust collector, which draws off the material when ground to the required degree of fineness. In point of fact these mills have replaced all other fine grinders in the various larger works in the United States where it is required to "kill the flake," a not very simple matter, and certainly not a desideratum with producers of flake.

THE MINING, SMELTING AND POWER PLANTS OF THE CANADIAN COPPER COMPANY.

By G. E. SILVESTER, Copper Cliff, Ont.

(Annual Meeting, Montreal, March, 1909.)

The name, "The Canadian Copper Co.," and the associated geographical appellation, "Copper Cliff," are rather misnomers, failing as they do to convey any hint of the major part of the business of the company, which is the production of nickel.

Copper Cliff is on the "Soo" branch of the Canadian Pacific Railway, about five miles from its junction with the main line at Sudbury. The company, incorporated in January, 1886, was originally formed, as the name indicates, to mine copper. In a short time, however, it was found that the principal metallic constituent of value in the ore was nickel, the copper being relegated to the position of a more or less troublesome by-product.

There was thus thrust upon this company the first opportunity of producing nickel in a large way.

It was, at that time, a sort of semi-precious metal, procurable only in small quantities, and for which there was a very limited demand.

The company set itself energetically to the task of solving the metallurgy of nickel, or, more strictly speaking, of copper-nickel, and much time and money were spent in experimenting to this end.

The first smelter, begun in 1888, was a heterogeneous patch-work, growing a patch at a time, here and there, as the company developed.

The second smelter, begun in 1899, embodied the best practice that experience had taught up to that time.

The units were small, however, hand labour largely prevailed, and the buildings, like those of the first smelter, were largely of inflammable construction. As a consequence, fires, more or less serious, were frequent. The demand for nickel products was continually increasing, due largely to the introduction of

Buildings at the Crean Hill Mine.

Hoist and Compressor at Crean Hill Engine House.

nickel steel, and it became apparent that any considerable extension of the system of small units then in vogue would make a very unwieldy plant, and increase the cost of operation out of due proportion.

During this time also, extensive exploration work by diamond drilling had been carried on, which proved the existence of very large ore reserves. The different metallurgical processes also had been perfected and were an assured success.

As a result, therefore, of the above considerations, it was decided in 1903 to build an entirely new smelting plant, using fireproof construction for the buildings, large units for smelting, and mechanical equipment wherever possible for the manipulation of materials.

The next step was the modernizing of the various mining plants, with the double object of increasing production and decreasing mining costs.

At the same time the question of power was taken into consideration. In the early years of the company's operations cordwood was plentiful and comparatively cheap. In a few years, however, owing to the rapidly diminishing supply, it had become necessary to substitute coal as a fuel for power production, in order to keep a sufficient reserve of wood within economic reach for ore roasting and similar uses for which wood is better adapted.

Coal, however, is expensive in Copper Cliff, and a prospective calculation of the annual consumption at the end of say ten or fifteen years, even with normal expansion, was sufficiently appalling to warrant steps being taken towards the installation of a hydro-electric equipment. A water power was procured, which would conveniently serve the outlying mines as well as the plants, mines, shops, etc., at Copper Cliff.

The only portion of the entire scheme of reconstruction which has not yet been completed are the shops. Plans have been prepared, however, for a complete new layout of modern fireproof shops, including machine, boiler, blacksmith, locomotive, car, carpenter, electrical repair and pattern shops, foundry and pattern storage.

The construction of these will probably be undertaken during the present year, having been delayed awaiting the extension of the smelter slag dump to accommodate them.

The following is a more or less detailed description of the plants referred to above, incidental reference only being made to the metallurgy of the ores:—

MINING PLANTS.

The Canadian Copper Company own and have operated during various periods, a number of mines in Copper Cliff and vicinity, but the present description will be confined to three which have been equipped with modern buildings and electrically operated machinery. These are Creighton, Crean Hill, and No. 2 mines.

Creighton Mine is situated about five miles, in an air line, west of Copper Cliff, on the Manitoulin and North Shore Railway (operated by the Algoma Central), over which line the ore is handled about eight miles to Clara Belle Jct., where it is transferred to the company's tracks.

There are two shafts in parallel planes about 330 feet apart.

No. 1 shaft, inclined 59 degrees, has two hoisting compartments and ladder way. It is still served by the original timber framed rock house with the interior somewhat modified.

No. 2 shaft, inclined 47 degrees, has, besides the ladderway, three hoisting compartments, one of which is intended more particularly for development work and hoisting barren rock, leaving the other two for the ordinary work of hoisting ore, without interference.

The rock house, 45′ x 90′, is of reinforced concrete up to and including the bin bottoms.

The bins, which are in three rows, served by three tracks running underneath, are 12 feet by 15 feet by 14 feet deep, built up of 3″ x 10″ plank laid flat and lined with 2″ plank.

The structure above the bins is of heavy timber framing with double wooden sheeting.

The ore is dumped on grizzlies at a height of about 70 feet above surface level. From the foot of the grizzlies, it is carried by massive curved chutes directly into two 18 x 30 jaw crushers, which are large enough to take anything that can be handled into tram cars underground. These chutes are removable in

Buildings at the Creighton Mine.

case ore should be encountered which would require sorting on the crusher floor. The wearing plates of the crushers are manganese steel. Each crusher discharges into a trommel screen, 36 inches by 10 feet, fitted with manganese steel plates with one inch perforations throughout, as only two sizes of ore, fines and coarse, are separated.

The coarse ore from each screen falls upon a 36-inch rubber picking belt, 50 feet long between centres, in two sections. There is also a screen and picking belt under the grizzlies. From these belts the ore and rock are distributed to their respective bins. The crushers, screens and belts are operated by two 50 horse-power constant speed induction motors.

The rock house has a capacity of about 1,200 tons in 24 hours.

The picking floor is steam heated. A few steam coils in the fines bins, covered with a false lining of steel plate, effectually prevent the freezing and hanging up of damp fines.

The tracks under both rockhouses are on a grade, so that empty cars can be placed on the upper side, then dropped through by gravity, and loaded without any further attention from a locomotive.

In the mine the drilling is practically all done with $3\frac{1}{8}$ and $3\frac{1}{4}$ inch standard type rock drills, and the blockholing by small hand air drills of the hammer type. The pressure at the drills runs about 95 pounds.

The tram cars are 18 inches gauge and 18 inches wheel base. The front and back journal boxes on each side are rigidly connected in a single steel casting, bolted under the side frame; ensuring a permanently true alignment of the axles. The wheels are 14 inches diameter of manganese steel, one fast and one loose on each axle. The cars weigh 2,000 pounds and hold about three tons.

The skips are 46 inches gauge, and hold a full tram car load. The wheels are of manganese steel 14 inches diameter, with broad treads on the rear wheels for dumping.

The track stringers are 8 x 10 inches, shod with 3 x $\frac{5}{8}$ steel straps. Guard timbers are 6 x 8 with $2\frac{1}{2}$ x $\frac{3}{8}$ straps.

The shafts and stations are lighted with incandescent lamps and equipped with electric hoisting signals.

In the stopes large acetylene torches are used, with individual lamps for drifts and confined spaces.

The mine pumps are of the vertical single acting, three cylinder, crank type, geared to 15 horse-power motors.

The engine house is 93 feet by 39 feet, with brick walls on concrete base. Steel columns built into the walls support a crane runway and steel roof trusses. The roof covering is 3 x 3 dressed lumber with tarred felt.

A high tension switch tower of brick, 10 feet by 11 feet, adjoins the building in one corner, and a transformer room 8 feet by 20 feet is walled off inside. A 10-ton hand power travelling crane runs the full length of the engine room. The floor is of reinforced concrete surfaced with cement tiles.

The equipment is as follows:—

Two electric driven mine hoists, a two-drum for No. 1 shaft, and a three-drum for No. 2 shaft.

The drums are 60 inches in diameter, and have a capacity of 1,000 feet of one inch cable in one lap. The drums are arranged to hoist singly or with any pair in balance. Each hoist is geared to a 150 horse-power variable speed induction motor, the hoisting speed being 600 to 800 feet per minute.

A 1,650 foot cross-compound compressor, direct connected to a 300 horse-power induction motor at 120 r.p.m. delivers air at 100 pounds pressure. An after-cooler is provided as well as an extra large intercooler. In addition to this, the condensed moisture is trapped in a special leg in the air line in the shaft.

A 1,000 gallon, 6-inch, 4-stage turbine fire pump, direct connected to a 150 horse-power induction motor, furnishes fire protection for all the mine buildings.

A 250 gallon, 3-inch, single stage turbine, with 5 horse-power motor, circulates cooling water to the transformers and compressor.

The office and warehouse are in one building, 30 feet by 60 feet. The walls are of brick, on concrete base with steel roof trusses and roof covering of hollow book tile with tar and gravel. The floor is of reinforced concrete. In the basement is situated the steam heating plant for all the buildings.

The dry, or men's change house, is 36 feet by 80 feet, of similar construction to the warehouse building. It is equipped with basins, shower baths, hot and cold water, closets and urinals.

There is a 12 x 16 open steel sanitary locker for each man. A private room is provided for foremen. The building is thoroughly heated and lighted and has a caretaker always in attendance.

The water for the various buildings and for fire protection is pumped from a small lake about 3,000 feet distant, into a steel tank holding 60,000 gallons, situated just outside the engine room.

The pump is a 250 gallon 4-inch, 2-stage turbine with 20 horse-power motor, in a small concrete building.

The tank is connected directly with the suction of the fire pump, and furnishes a gravity supply for the buildings generally.

Crean Hill Mine is situated about 14 miles, in an air line, west of Copper Cliff, and about 3½ miles northeasterly from Victoria Mines Station on the "Soo" line of the Canadian Pacific Railway, with which it is connected by a spur line of railway, built and operated by the company. The ore is placed on siding at Victoria Mines and from there is handled by the Canadian Pacific to Copper Cliff.

Fifty-ton, steel, hopper bottom cars are used in this service.

Crean Hill is the most recently developed of the company's mines, operations having begun there in 1906.

There is one shaft here, inclined 57 degrees, and having three hoisting compartments besides ladderway.

The rockhouse, warehouse and office building, and dry are duplicates of those at Creighton.

The engine house is of similar construction, but somewhat smaller, 39 feet by 75 feet, requiring to accommodate only one hoisting engine. The equipment is precisely the same as at Creighton, omitting the two-drum hoist.

The heating boiler is housed in one end of the blacksmith shop, built of brick and stone. This shop, as well as that at Creighton, is equipped with a drill-sharpening machine operated by compressed air, with a special oil forge for heating steel. The ordinary forges use a jet of compressed air with blow-jack attachment giving induced draft.

No. 2 Mine is situated within the corporation limits of the Town of Copper Cliff, and is served by the company's own yard tracks. The original rockhouse is still in use, somewhat modified to provide for electrical operation.

The engine house is a duplicate of that at Crean Hill with the omission of the high tension tower, the close proximity of the main sub-station at the smelter rendering this unnecessary. The equipment is the same as at Crean Hill, except that the hoist is a two-drum machine like that serving No. 1 shaft at Creighton. The supplies are served from the central warehouse at the smelter.

The main idea in equipping these three mines was to standardize the various machines as far as possible, making repair parts interchangeable, and thus minimizing the number of these to be carried in stock.

SMELTING PLANT.

Before entering upon a description of the smelting plant proper, it may be stated, that, while all the ore from the Crean Hill mine goes direct to the furnaces, a large part of that from the other mines is first roasted. Open air heap roasting is practiced, using cordwood for lighting, the heaps containing from 2,000 to 3,000 tons each. The roast yard is situated between Clara Belle Junction and the smelter. The roast ore is loaded by steam shovel into 50-ton drop-bottom cars and taken to the storage bins as required.

The smelter treatment consists of two operations, matting in blast furnaces and bessemerizing.

The site of the present smelter was decided upon, after a careful contour survey covering all the available ground in the vicinity. The grade of the receiving track, on top of the storage bins, having been fixed at 67 feet above the smelter yard grade, it was necessary to fit these two governing levels into the topography in such a way as to give the easiest possible railway connection to each, and at the same time obtain a good slag dump, with sufficient area and depth to last for many years without elevating slag. These several conditions are all met in the present site. Reference may be made to the accompanying drawing.

The storage bins, dust chamber, stack, sampling building and laboratory are all built on solid rock, and the furnace building, steam power house and electrical substation almost entirely so. The other buildings were constructed later, on 15 or 20 feet of poured slag.

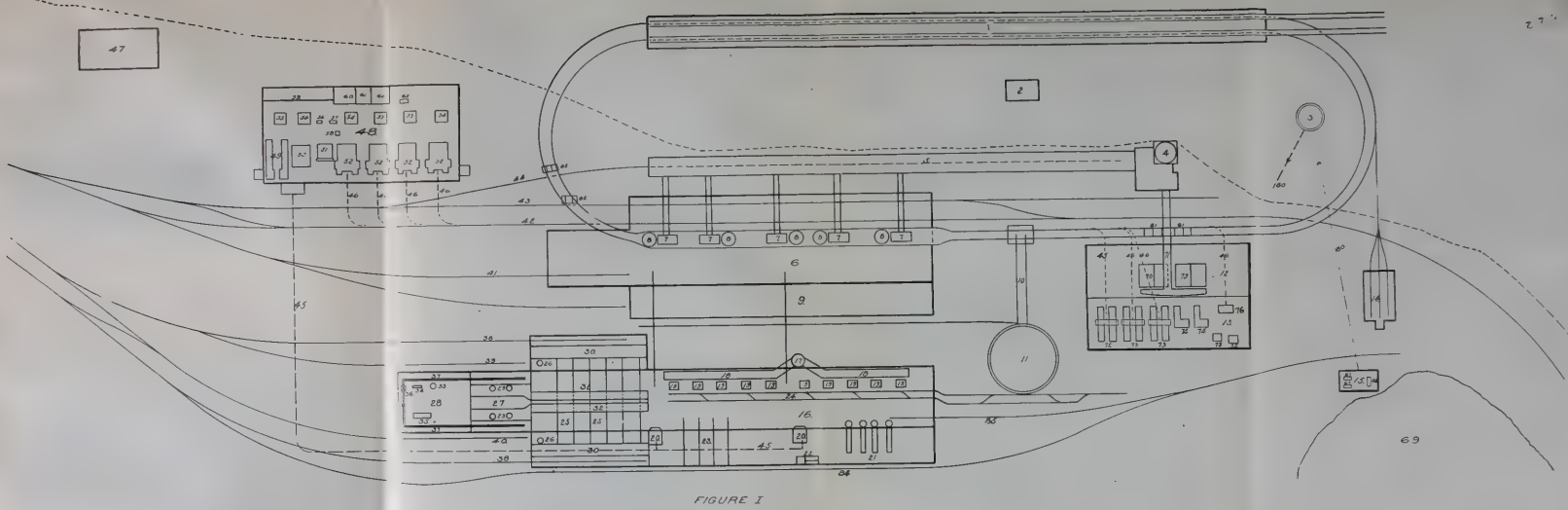


FIGURE I

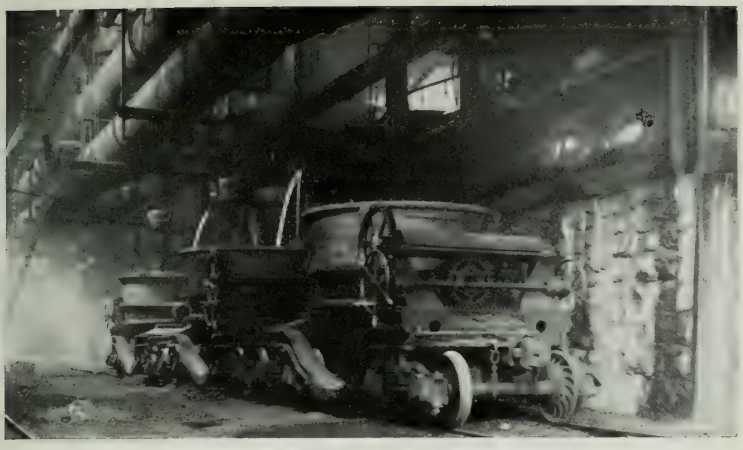
FIG II FIG III FIG IV FIG V

FIGURE I.—General Plan of Smelting Plant. FIGURE II.—Section thro' Mill Dept. of Converter Building. FIGURE III.—Section thro' Blowing Dept. of Converter Building. FIGURE IV.—Section thro' Refining Dept. of Converter Building. FIGURE V.—Section thro' Furnace Building Dust Chamber and Bins

1. Storage Bins.
2. Hoist House for Slag Skips.
3. Water Tank.
4. Stack.
5. Dust Chamber.
6. Furnace Building.
7. Blast Furnaces.
8. Settlers.
9. Shed on Furnace Building.
10. Slagway.
11. Slag Casting Machine.
12. Boiler Room.
13. Engine Room.
14. Sample House.
15. Pump House.
16. Converter Blowing Dept.
17. Converter Stack.
18. Converter Flue.
19. Converter Stands.
20. Converter Pulpits.
21. Casting Moulds.
22. Escalator.
23. Skulling Tracks.
24. Converter Slag Tracks.
25. Refining Tracks.
26. Shell Drying Stacks.
27. Pug Mill and Bin Dept.
28. Tris-lining and Drying Dept.
29. Pug Mills.
30. Wood Platforms.
31. Refining Dept.
32. Refining Platform.
33. Crusher.
34. Screen.
35. Clay Drier.
36. Rolls.
37. Conveyers.
38. Wood Tracks.
39. Quartz Track.
40. Clay Track.
41. Furnace Track.
42. Slag Track.
43. Slag Switching Track.
44. Dust Chamber Track.
45. Converter Blast Pipes.
46. Furnace Blast Pipes.
47. Laboratory.
48. Substation.
49. Converter Blowing Engine.
50. Converter Blowing Engine.
51. 100 lb. Compressor.
52. Furnace Blowing Engines.
53. 900 H.P. Motors.
54. 500 H.P. Motor.
55. 1,200 H.P. Motor.
56. Motor-Generator Set.
57. Frequency Changer.
58. Heating Blower.
59. Switchboard.
60. Transformer Rooms.
61. High Tension Tower.
62. Fire pump.
63. Lining Bin.
64. Travelling Cranes.
65. Tamping Machines and Jibs.
66. Travelling Crane.
67. 8 inch 1,500 Gall. Turbine Pumps.
68. 14 inch, 5,000 Gall. Turbine Pump.
69. Reservoir.
70. Boilers, 400 H.P. each.
71. Boiler Flue.
72. Steam Converter Blower.
73. Steam Furnace Blowers.
74. Steam driven Generators.
75. Two 225 H.P. Motors.
76. Rotary Blower.
77. Matte Ladle.
78. Cinder Car.
79. Downpipes.
80. Furnace Water Lines.
81. Boiler Room Coal Pocket.
82. Locomotive Coal Pocket.
83. Shell on Refining Car.
84. Matte Loading Track.
85. Converter Scrap Track

General View of Smelter, looking West.

Rear of Furnaces showing Downtakes and Dust Chamber.



Rear of Furnaces Showing Cinder Cars.

Interior of Blowing Department, Converting Building.

The Storage Bins are of massive timber construction, with bents 6 feet centres on masonry footings. They are 700 feet long, 30 feet wide and 32 feet high, carrying two standard gauge tracks at 15 feet centres. The bins are covered with a running shed having a continuous louver ventilator, and sheeted and roofed with 3/16 inch asbestos lumber. The total storage capacity is about 400,000 cubic feet. Under the bins and on the same level as the furnace charge floor run two parallel tracks, 36 inch gauge, and 15 feet centres. The bin bottoms are double hoppered with discharge gates every 6 feet, directly over each of these tracks. The gates are a patented type, convex on the under side and hand operated by geared cranks.

At one end of the bins are three-ton suspended track scales on each track, with the beams and weigh clerk housed between the tracks. Alongside are small open bins for adjusting the components of the charge. Two more of these scales will be installed near the centre of the bins to relieve the pressure on the present ones.

The centre line of the ore bins is parallel to that of the furnace building and 200 feet distant from it. The tracks under the bins are carried around in a semi-circle at each end and through the furnace building, one track on each side of the furnaces, thus forming a double track belt line, with crossovers at convenient points.

These tracks are covered between buildings with a wooden shed; and for a considerable distance along the furnace slag track are carried on a trestle resting on 14 foot masonry piers. This prevents danger of fire from slopping of hot slag from the cinder cars. In this trestle, under the charge tracks, are coal pockets with chutes which discharge in front of the boilers in the steam power house, described later. There are also two coaling pockets for locomotives.

Around this belt line the furnace charging trains are operated, running always in the same direction. Each train consists of seven or eight side roll-dump cars, weighing about 1,500 pounds and holding about 3,000 pounds of ore; hauled by a 5 ton electric locomotive with 1,200 pound drawbar pull at 6 miles per hour, equipped with overhead trolley and using direct current at 250 volts.

The tracks are 56 pound steel, copper bonded throughout.

The charge cars are 6 feet long over all, this being also the length of furnace charge doors, and the centre to centre spacing of bin gates.

The charging trains also supply the coal pockets referred to above, the coal being weighed in transit.

The Furnace Building is 370 feet long and 86 feet wide, with a leanto shed 30 feet wide and 280 feet long on one side. It is of steel construction throughout, except one side wall of brick, with heavy pilasters, which carry one track of the crane runway, and having 8 feet arched doorways every 20 feet. The roof covering is reinforced concrete tile. A section of roof 12 feet wide, in each space between furnaces, is raised two feet above general roof level for ventilation. A monitor, enclosed with louvers, is also carried up 8 feet above the main roof around each furnace. The lower part of the building is divided longitudinally into three portions or bays.

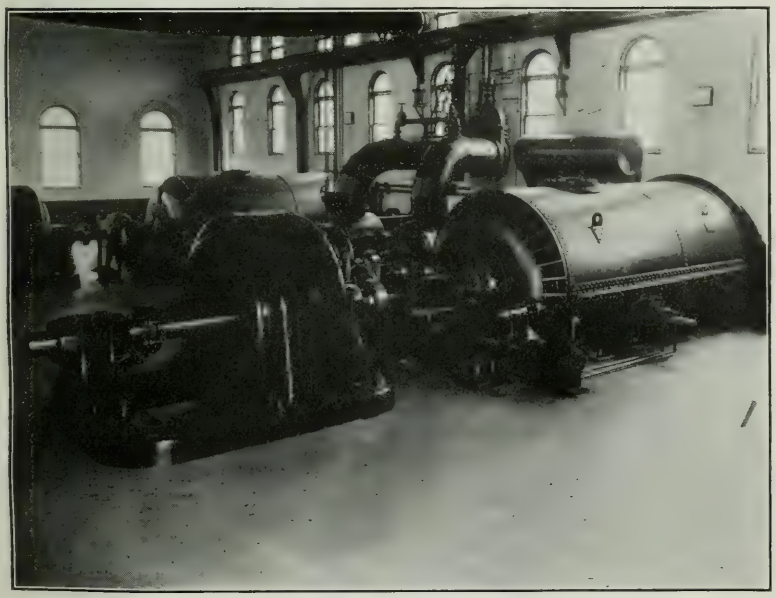
(*a*) The slag floor at the back, 33 feet wide, served by two standard gauge through tracks.

(*b*) The matte floor in front, 33 feet wide, served by two 50 ton-20 ton electric ladle cranes of 32 feet 10 inches span, and by a railway track running about 80 feet into one end of the building.

(*c*) The furnace and settler floor in the centre, 20 feet wide and 10 feet above the balance of the floor. The raised portion consists of massive masonry walls, which form the foundations for the furnaces and settlers, and for the columns which carry the charge floor and crane runway. These walls are filled in between and floored over with concrete, which is carried out over the matte floor about 9 feet on steel supports, forming a continuous tapping platform and furnace runway. The charging floor is 35 feet above the matte and slag floor, and 25 feet above the furnace floor. It is 30 feet wide, of reinforced concrete on heavy steel framing, with sides sheeted up to the roof, forming a separate enclosure.

The Blast Furnaces, five in number, are of the rectangular water-jacketed type, 50 x 204 inches inside at the tuyères, 19 feet high from the hearth plate to the charging level, and rated at 500 tons per day. They are spaced in line, at 61 feet 6 inches centres, with their longitudinal centre line coincident with that of

Casting Machine for Converter Slag



Turbines and Generators in Power House at "High Falls."

the building. The supporting frame is of heavy steel construction, the charge deck of cast iron. The hood or superstructure above the charge deck is of fire brick, with 18 inch walls, built into a skeleton of very heavy structural steel. The end walls unite in a catenary arch to form the roof, the top of the arch being 33 feet above the charging level, making the total height of the furnace 58 feet above the tapping platform. The side walls are vertical and in one of them is the down-take opening, with its centre 27 feet above the charge floor.

The downtake is 8 feet in diameter, lined with 4 inches of fire brick for the first 20 feet. It inclines 30 degrees in a straight line from the furnace to the dust chamber, passing over the slag tracks. The design of hood on these furnaces has given great satisfaction in the way of perfect draught, and almost absolute freedom from scale. The hearth plate is supported on jacks on a concrete pedestal. There are two tiers of water jackets, the lower or tuyère jackets 8 feet, and the upper 6 feet 4 inches high. Cast iron tuyère jackets have been substituted entirely for the ordinary steel plate type formerly used, and still used for the upper tier. They have water circulating pipes cast into an otherwise solid slab, with stiffening flanges.

The settling wells are 16 feet in diameter and 5 feet 6 inches high. Settler, furnace hearth and spout are lined with chrome brick. Water-cooled cast iron slag spouts on the settlers discharge into 25-ton cinder cars, with sectional cast iron bowls, rack and worm geared, on standard gauge trucks. Small catch-pots, operated by compressed air crawls, receive the slag streams during cinder car shunts.

The matte from the settlers is tapped into 7-ton steel plate ladles, clay lined. These ladles are placed by the travelling cranes on low transfer trucks and hauled by a compressed air winch across into the converter building.

The slag spout and tap hole on the settler are diametrically opposite, and the furnace spout discharges midway between them.

The jacket water overflows into two continuous cast iron launders, on either side of the furnaces, sloping both ways from the centre furnace, and thence flows through 20 inch drains to an open cooling reservoir.

As the water supply is limited, and the furnaces alone use about 1,000 imperial gallons per minute each, the most of this is pumped back from the reservoir and used over and over. For this service three pumps are installed, two 8-inch, 1,500 gallons, and one 14-inch, 5,000 gallons. All are single stage turbines direct-connected to constant speed induction motors. These discharge through an 18-inch flanged cast iron pipe into a reinforced concrete tank 25 feet diameter and 32 feet high. Duplicate cast iron mains, connected to this tank, run on either side of the furnaces, just under the charge floor. The tank is also connected to the smelter supply main, the static head of the latter being just balanced in the tank. This arrangement gives a very steady pressure on the furnaces, the head being about 28 feet above the jackets.

The Dust Chamber is of 5/16 steel plate of the balloon type, 20 feet diameter, 34 feet high and 500 feet long, supported on steel columns, with expansion joints about every 60 feet. The only lining is a section about 12 feet square, opposite each downtake opening. The bottom has hoppers and clean out doors every 6 feet. These discharge the flue dust directly into cars on a continuous track underneath.

The Stack is 210 feet high and 15 feet inside diameter at the top. The upper 150 feet is circular, built of perforated radial stack brick; the base is 24 feet square, of granite masonry, with circular lining of fire brick. This stack also accommodates the steam power house boilers.

Converter Building.—This building is of steel construction throughout, extra braced on account of the heavy travelling cranes. The main building is 522 feet long, 60 feet wide and 47 feet to the roof trusses, with leanto sheds 30 feet wide, 392 feet long on one side, and 112 feet on the other. A monitor 24 feet wide, and 8 feet high, with louvers, runs the entire length except the end bays. The roofing is of reinforced concrete tile and the sheeting of galvanized corrugated iron, except 130 feet at the relining end, which is covered with cement plaster on metal, giving greater protection against frost. The building contains four departments; 280 feet in length being provided for blowing, 112 feet for relining, 60 feet for pugmills and storage bins for lining materials, and 70 feet for quartz crushing and clay drying.

A crane runway, of 55 feet 8 inches span, covers the blowing and relining sections. Two 50 ton-20 ton electric cranes are installed, main hoist lift 18 feet per minute, auxiliary hoist lift 36 feet per minute and bridge travel 200 feet per minute. Both these cranes and those in the furnace building, which are of somewhat slower motion, are equipped with variable speed induction motors.

There are ten converter stands, with 30 shells 84 by 126 inches. The stands are arranged in two batterie of five each. Each stand is operated by a 30 horse-power variable speed induction motor, worm geared. The shells may be rotated through a complete circle.

An operating pulpit is supplied for each battery of stands, elevated 10 feet above the floor, giving a complete view of the operations through plate glass windows. A 36-inch blast pipe is carried behind the pulpits through the shed trusses, with 24-inch outlet at each pulpit, leading to a manifold underneath, from which individual 12-inch cast iron pipes are carried underground to each stand. The riser pipe at each stand is connected by a swivel goose-neck union, and has a return bend at the top, which rises above the matte level, preventing any possibility of matte backing into the blast pipe, if the blast goes off. The riser is clamped to an I-beam post with screw attachment for adjusting the connection. In the pulpit the operator has one hand on an electric controller and the other on a hand wheel which operates the corresponding blast gate on the 12-inch pipe below. Electric push buttons, opposite the stands, record the operating signals on annunciators in the pulpits.

The steel converter flue, running at the back of the stands and under the crane runway, is 4 feet wide by 13 high, with a swinging hood over each stand. It is connected to a central unlined steel stack, 125 feet high and 12 to 9 feet diameter, just outside the building.

The converter slag, which is a revert to the blast furnaces, is skimmed direct into sectional cast iron pots, holding about 2½ tons, mounted on 42-inch gauge trucks. These are hauled by a five ton steam locomotive to a circular slag-casting machine, 65 feet in diameter, driven by a 15 horse-power motor. The cast iron moulds travel about 20 feet per minute and are automatically

dumped into two skips, which are hauled up an inclined skipway by an electrically driven hoist and dumped into steel bins over the furnace charge tracks.

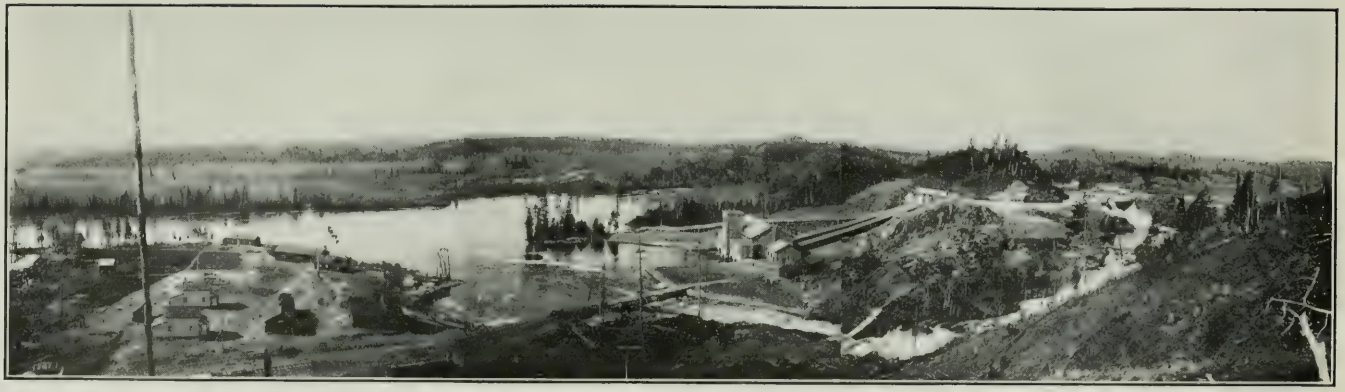
Quartz and local clay for lining the converter shells are brought in on grade tracks, on either side of the building. The clay, when damp or frozen, is put through a rotary double cylinder dryer, 70 inches diameter by 30 feet long, coming out in small pellets.

The quartz is fed through a gyratory crusher, screen and rolls, delivering a $\frac{3}{4}$ inch product.

Clay and quartz are elevated to 14-inch conveyer belts which deliver them to their respective bins over the pugmills on either side. These bins are of $\frac{3}{8}$-inch steel, of the suspended catenary type, 21 feet wide and 22 feet deep, in two parallel rows each 60 feet long, giving a total capacity of 800 tons of quartz and 500 tons of clay. Small swinging end-dump cars, running on tracks under the bins are loaded from gates in the bin bottoms, and dump direct into the pugmill pans, which in turn discharge direct into similar cars running on tracks on the relining platform. There are three pugmills, belt driven by individual motors of 30 and 35 horse-power. A 66 horse-power motor drives the crushing, elevating and conveying machinery, and a 15 horse-power motor the clay dryer.

The relining platform is 20 feet wide and 10 feet high, of reinforced concrete on steel framing. It extends out from the pugmills 112 feet under the crane runway. The shells are placed for lining on special steel cars running on six transverse tracks, extending under the platform and out into the sheds at either side. There are thus 12 lining positions. The parting line of a shell, sitting on its car, is flush with the top of the lining platform. The linings are tamped around cast iron moulds or formers with compressed air tampers. These consist of a modified rock drill mechanism with a heavy cast iron cylinder jacket to absorb the vibration. They are suspended by trolley chain blocks from jib cranes attached to the building columns. After being lined the shells are moved on their cars under the drying flues and alongside the wood platforms. These flues lead to steel stacks, 75 feet high, which carry the smoke clear of the building.

When burnt out, the shells are placed on cars, on four skulling tracks which run out under the shed. Between these tracks



Panoramic View of Power Plant at High Falls.

are skulling platforms from which the old linings, after removal from the shells, are wheeled in barrows on to flat cars alongside.

The flue dust and scrap, which are constantly accumulating from the blowing operations, are loaded on flat cars which stand continually on a track running into the end of the building.

The converter matte, which is the shipping product, is poured from the shells into crane ladles and cast through chutes on to flat sectional cast iron moulds, 4 feet by 24 feet by 4 inches deep. It is then cooled, broken up, shovelled into barrows and loaded by an electric driven escalator into box cars.

The Power Plant.

When the present smelter was blown in, the construction of a hydro-electric plant had not been considered. The various mines and shops, etc., had their individual steam equipments, and for the first two years the smelter was operated by steam generated power.

The steam power house is 100 feet by 160 feet. The walls are brick with masonry foundations. Steel trusses support a roof of hollow book tile covered with plastic slate. A longitudinal brick fire wall runs through the centre of the building and divides the engine room from the boiler room. The floors are of reinforced concrete.

There are two pairs of 400 horse-power water tube boilers furnishing superheated steam at 160 pounds pressure; and the necessary feed pumps, feed water heaters, hot well pump, dry vacuum pump, and a 24-inch barometric condenser.

In the boiler room are also a 1,000 gallon underwriter pump, 700 gallon duplex furnace feed pump, and a cross-compound 18 x 11 x 18 compressor.

As all the water used at the plant contains from 15 to 20 parts per million of acid, it was necessary to install a purifying plant. This supplies also the locomotive water tank.

In the engine room is the following equipment:—

Two furnace blowing engines, cross-compound Corliss steam, 13 x 25 x 42, duplex air, 57 x 42, giving a pressure of 60 oz. Capacity 20,000 feet per minute at 85 r.p.m.

One converter blowing engine, cross-compound steam, 15 x 30 x 42, duplex air, 40 x 42, giving blast pressure up to 15 lbs. Capacity 10,000 feet per minute at 85 r.p.m.

Two generator sets, each consisting of 350 horse-power tandem compound Corliss engine, 13 x 26 x 24, 200 r.p.m. direct-connected to 200 k.w. 600 v. 3-phase, 25 cycle generator, with 11 k.w. belt driven exciter.

One 30 k.w. motor generator set, delivering direct current at 250 volts.

All this equipment is kept as a reserve in case of serious accident to the hydro-electric plant. One boiler is kept under steam, banked in summer and supplying steam heat to the various buildings in the vicinity in winter.

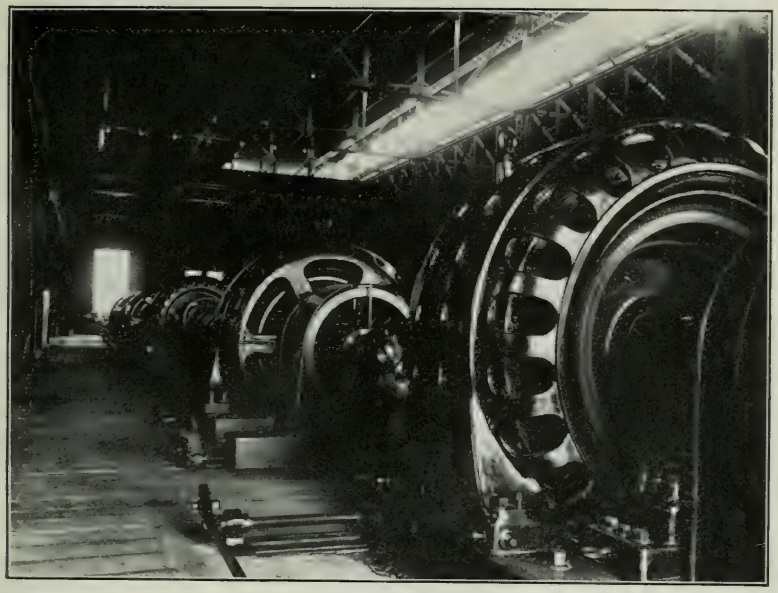
For lack of room in the electrical sub-station, there is installed in the steam power house also one 300 foot rotary furnace blower, rope driven by two 225 horse-power induction motors. There are three speeds, the maximum giving 30,000 cubic feet per minute.

The Water Power referred to above was developed by a subsidiary company, formed for this and other purposes, known as the "Huronian Company." The site is at High Falls on the Spanish River in the Township of Hyman, about four miles from the "Soo" line of the Canadian Pacific Railway, at a point about 23 miles west of Copper Cliff station. It is connected with the railway by a spur line from Turbine station.

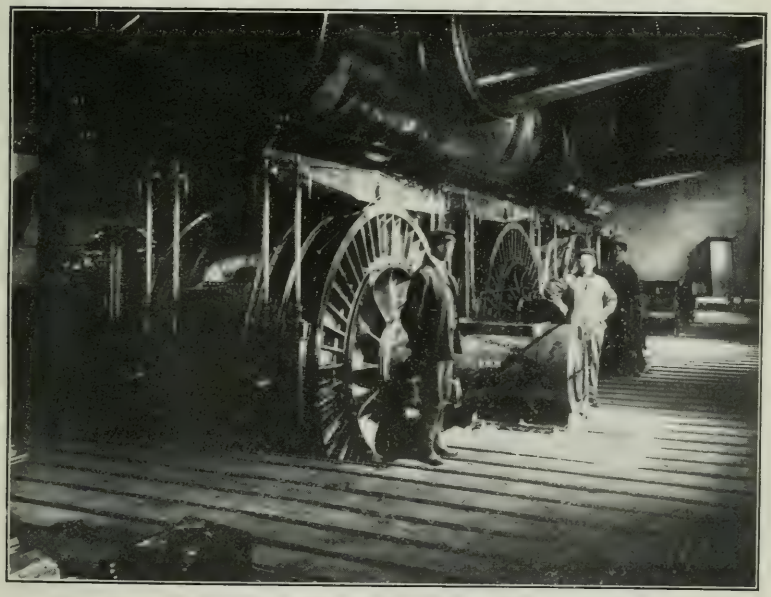
Work was begun on this spur line in the spring of 1904, and on the power development proper in the following September. Power was turned on at Copper Cliff in February, 1906. The power house is situated on the lower point of an island in the river, across which the water is carried. The natural head was 67 feet, which has been raised by the dams to 85 feet. The effective water-shed is upwards of 2,000 square miles, practically all unimproved, containing a large area of lakes.

The dams are all of concrete construction on solid rock. This work was carried on continuously throughout the winter of 1904-05.

Log slides and booms had to be provided, to handle the very large cut of timber which is annually driven down the Spanish River.



Blowing Engine Motors at Smelter Sub-Station.



Furnaces Blowing Engine at Smelter Sub-Station

From the bulkhead wall, three 9-foot steel penstocks for the generators, and one of 3 feet for the exciters, are carried down the slope to the power house.

The power house is of brick on a concrete substructure, with steel roof trusses.

The roof covering is 2 x 4 lumber on edge, sheeted with galvanized iron. The building is 106 feet long by 71 feet wide, with an annex 33 x 30 at one end for workshop and heating boiler. The blower system of heating is used.

The generator room is 55 feet wide, leaving 16 feet along one side for the transformer rooms and switch tower, which are separated from it by fireproof brick walls and steel doors.

There is space for four generating units, three of which are installed. Each unit consists of a 2,000 k.w. generator, 3-phase, 25 cycle, 2,400 volts, direct-connected to the shaft of a 3,550 horse-power turbine, on which are mounted two 34-inch bronze runners in a single case.

The head is 85 feet and the speed 375 r.p.m.

There are two exciters of 200 k.w. each, either of which can furnish excitation for four generators. Each exciter is driven by a small turbine, direct-connected.

Three sets of transformers, of three each, step up the voltage from 2,400 to 35,000, at which it is transmitted.

The operators' bench board occupies a central elevated position in front of the switch tower, giving a full view of the generator room, and the switching operations in the tower. All switches are distantly controlled, and there is nothing higher than 125 volts on the board.

A small motor-driven air compressor is installed for cleaning purposes, and for handling oil by air pressure.

For fire protection there is a 500 gallon 2-stage turbine pump, direct-connected to a 50 horse-power d.c. motor, operated from the exciter. The pump suction is connected to the penstocks.

No trouble has been encountered in this plant from frazil, there being no rapids upstream for six miles.

The penstocks, bulkhead gates, and screens are housed, and the use of a small amount of current at critical points effectively prevents the building up of ice in the tubes.

Transmission Line.—The main transmission line is about 30 miles long, from the power house at High Falls to the sub-station at Copper Cliff, for the most part on its own right of way, 100 feet wide, all cleared. It is of double cedar pole construction, with poles at 8 feet centres, bolted to a common crossarm.

There are two independent 3-phase circuits of No. 1 wire, arranged in two equilateral triangles, 4 feet apart, and 4 feet to a side. One circuit is transposed and the other straight.

The pole stands are placed 120 feet apart.

Branch lines of single pole, single circuit construction, run from the main line to Crean Hill mine and Creighton mine, each being about 3½ miles in length. These are both connected to the same main circuit with aerial switches.

Lightning arresters, of the horn type, are provided outside the power house and the sub-stations at Copper Cliff, Creighton and Crean Hill.

A telephone line runs direct between the switchboards in the power house and smelter sub-station, along the transmission line. It is carried on a short crossarm, 6 feet below the main crossarm with the wires transposed every fifth pole. It gives perfect service.

A second telephone line, carried for the most part on the poles of the Canadian Pacific Railway's telegraph, connects the terminal stations with the Copper Cliff central, and also with Crean Hill and other points between.

Crean Hill Sub-station.—In a separate fireproof room, walled off from the engine room, are placed three 175 k.w. water cooled transformers, 35,000 to 550 volts.

In the engine room are the necessary switch board panels for control and distribution.

Creighton Sub-station.—The equipment here is precisely like that at Crean Hill, except that the transformers are of 275 k.w. capacity each.

No. 2 Mine Sub-station.—Here the current is obtained from the main sub-station at 2,300 volts, and the transformers are natural cooled, of 125 k.w. capacity, 2,300 to 550 volts.

Smelter Sub-station.—This is the main distributing station of the system, and supplies motors in the building itself, and elsewhere, having a total capacity of over 7,700 horse-power, besides

arc and incandescent lighting for the smelter, shops, etc., and the town of Copper Cliff. Most of the circuits in the furnace and converter buildings are placed underground in fibre conduits, laid in cement.

The building is 92 feet wide, by 194 feet in length.

The foundations, walls and floor are of concrete. Steel roof trusses are carried on a central row and two outer rows of steel columns, the latter being built into the concrete walls. Two ten-ton hand power cranes are carried on two parallel runways extending from end to end of the building.

The roof is of hollow book tile, covered with tar and gravel.

The transformer rooms and high tension switch tower are arranged along one side, separated by fireproof walls.

The following equipment is housed in this building:—

Two banks of transformers, three each, 667 k.w., 35,000 to 2,400 volts.

Three transformers, 175 k.w. each, 2,400 to 575 volts.

Most of the motors outside this building operate at 550 volts.

Fifteen panel switchboard.

Storage battery for controlling switches.

Four furnace blowing engines, duplex, radial valve, 70 x 42, capacity about 24,000 cubic feet of air per minute, delivered at 50 oz. pressure with 75 r.p.m. These are driven with fourteen $1\frac{1}{2}$ inch ropes, English system, two by 600 horse-power and two by 500 horse-power motors.

The motors have special pole changing controllers giving three speeds.

Each of these blowing engines is connected to one or more furnaces by a 48-inch blast pipe, carried on steel trestles.

Two of these blast pipes are carried through, past the furnaces, to the steam power house, where they are connected to the rotary blower, and the two steam blowing engines previously referred to.

Each blast pipe is equipped with a 22-inch multiple spring blow-off; and each engine with automatic gravity oiling system, revolution counter, recording pressure gauge, etc.

One converter blowing engine, duplex, Corliss valve, 40 x 36, capacity 10,200 cubic feet of air per minute at 12 lbs., 100 r.p.m., supplying four converter stands, driven by 500 horse-power motor with sixteen $1\frac{1}{2}$ inch ropes.

One converter blowing engine, duplex, Corliss valve, 60 x 48, capacity 20,700 cubic feet per minute at 12 lbs., 70 r.p.m., supplying 8 converter stands, driven by 1,200 horse-power motor, with forty-two $1\frac{1}{2}$ inch ropes.

These two engines are each equipped with automatic unloading device, gravity oiling system, recording gauge, etc. They both discharge into a common receiver, from which a 36-inch blast pipe is carried on a steel trestle to the converter building.

One cross-compound 100 lb. air compressor, 15 x 24 x 24, capacity 1,500 cubic feet per minute, direct-connected to a 300 horse-power motor at 120 r.p.m. The air from this machine is piped all over the plant, and is used for various purposes, such as blowing out motors, tamping converter linings, shell drying, operating air lifts on furnace doors and elsewhere, driving air winches and hoists, air tools of various kinds, forges, etc.

One 1,000 gallon 6-inch 4-stage turbine fire pump, direct connected to a 225 horse-power motor. This pump, as also the underwriter pump in the steam power house, is connected to a series of dry fire lines, which are laid around the smelter buildings, with hydrants and hose houses at frequent intervals. A closed circuit electric fire alarm system is in service.

One 100 k.w. motor-generator set, 575 a.c. to 250 d.c., operating the electric locomotives for furnace charging. This is the only direct current used anywhere in the system.

One 75 k.w. frequency changer, delivering 60 cycle alternating current for arc lighting. About 50 enclosed arc lamps are used for lighting the furnace and converter buildings, and the smelter yard, and 25 are supplied to the town of Copper Cliff for street lighting.

The building is heated by air, blown over coils by a motor driven fan and distributed through ducts and floor registers. With the blowing engines removing usually over 100,000 cubic feet of air per minute, any ordinary means of heating would be futile, were it not so arranged that the engines receive their air direct from outside the building, through a large cold air duct in the basement, to which all the initake valves are connected.

A complete system of electric signals, with gongs and colored lights, for the operation of the various blowing engines, connects this building with the furnace floor and the converter pulpits.

This sub-station, in addition to serving the smelter, is also the distributing point for No. 2 Mine, for the shops, for municipal and domestic lighting, and for the Cobalt smelter, which plant does not come within the scope of this paper.

The Sampling Plant is a three storey building, 30 x 48 feet. The upper floor is on a level with the furnace charging tracks, to which it is connected by a track carried on a trestle and forming a tangent to the curve at one end of the belt line. There are 24 bins, into which samples can be dumped direct from cars brought in by electric locomotive. These bins discharge into small tram cars on the crusher floor below.

Two small jaw crushers are used, with "Duplex" samplers. Two laboratory crushers with riffle samplers from the next step, from which the material goes to various grinders and pulverizers for final division.

All the discard goes to a common bin at the bottom of the building, from which it is hoisted in regular furnace charging cars by an electric elevator at the end of the building. This serves also to hoist to the crusher floor, samples which originate on the lower yard level.

The crushers and elevator are operated by a 15 horse-power motor, and the smaller machines by a 5 horse-power motor.

The Laboratory is 34 feet by 79 feet, of concrete, brick and steel construction, with book title roof. Care was taken to make it fireproof, as two laboratories had previously been destroyed by fire.

The building consists of one storey, with 9-foot basement. The main floor contains an analysis room, 32 x 40, and four smaller rooms, each 13 x 18, which are the head chemist's office, the balance room, the H2S room, and the bacteriological analysis room, which also contains an assay furnace. All partitions are brick.

The large room is open to the roof, and in each gable is a bull's eye window with an electric ventilating fan.

The hood is of down-draft construction, with top light. It is made of concrete, iron and glass, and is ventilated by a suction fan in the basement.

Electric hot plates are used, with the temperature controlled by plugs.

Acetylene gas is used for the Bunsen burners.

In the basement, which has a separate outside entrance, are the store rooms, lavatory, private research room, photographic dark room, and the heating system, which is similar to that in the sub-station.

Warehouse.—A central warehouse building has been constructed at the smelter, which serves as the main distributing point for supplies for the various plants and mines.

The building is 60 feet by 150 feet, two storeys and basement, built of concrete, steel and brick, with concrete tile roof. The floors are of reinforced concrete, designed for 300 and 150 pounds per square foot.

There is an unloading platform 20 feet wide the full length of the building, and a three-ton electric elevator serving all three floors.

In this building are also the purchasing office and the electrical repair shop.

The Shops.—These include machine, locomotive, blacksmith, boiler, car, carpenter, and pattern shops; foundry and pattern storage. These buildings are at present rather inconveniently situated, and quite inadequate for the machines installed, and the volume of work done. As mentioned above, larger ones of modern construction are to be built. Most of the ordinary repairs and renewals for all the plants are executed here, including car and locomotive work.

Water Supply.—The general water supply is obtained by gravity from two small lakes. A heavy concrete dam has been constructed at their outlet, forming a very considerable reservoir, from which a 16-inch cast iron main leads directly to the smelter. Other mains supply the shops, etc., and the town of Copper Cliff.

Transportation.—To furnish efficient transportation service to the various departments, considerable equipment and organization is necessary.

There are about 25 miles of tracks in service, mostly laid with 80 pound steel.

Two standard hundred-ton track scales are installed, one at the roast yard, and the other in the main yard near the shops.

Both are properly housed, the latter containing also the transportation offices.

The motive power consists of nine locomotives. Four of these are 117-ton, six wheel switching engines. Two others are about 90 tons each, and three about 60 tons. There are also a 15-ton capacity locomotive crane, and two gasoline motor cars. The rolling stock includes twelve 50-ton dump cars, 125 flat cars, and 125 five-ton dump cars, besides test car, wrecking tool car, and flanger.

For housing the motive power there is provided a six-stall Round House, of steel, brick and concrete construction, with concrete floor and pits. This is served by a standard 70-foot, half deck steel turntable, with concrete foundations.

A complete telephone system, with twenty-four hour service, connects the general office with all departments, including the outlying mines and the power plant.

For the physical well-being of the employees, there is a thoroughly equipped modern hospital, with a staff of physicians and nurses.

There is also an accident insurance fund administered by a committee of the employees.

From the assurance of eminent authorities from almost every country who have visited this plant, the Canadian Copper Company feel justified in believing that, after the completion of the new shops, they will have, while not the largest, at least, all things considered, one of the best smelting plants in the world.

SOME NOTES ON GAS POWER AND ITS APPLICABILITY TO MINING.

By A. BURNETT, Greenwood, British Columbia.

(Western Branch Meeting, Greenwood, Jan., 1909).

To mining engineers any form of prime mover which will reduce the cost of extracting a ton of ore is worthy of attention and of the direction of effort towards the application thereof to the special conditions which obtain in mining.

Of the prime movers at our command, there are three capable of practical application, namely: steam power, gas power and water power—the last-named being usually rendered available by the medium of transmitted electricity, and of this we have an excellent example in the Boundary district.

In districts less favoured with respect to water power, where the mining conditions are somewhat similar to those in the Boundary, necessitating large output at low cost and where water is scarce and fuel expensive, gas power, with its attendant economies in water and fuel, suggests a means of generating power at a cost very much lower than can be hoped for from steam.

I propose to offer some remarks on the status of the gas engine, prefacing these with a brief outline of the philosophy of the gas producer, and concluding with some remarks on the probable direction of the expansion of the industry.

The gas engine, or more properly speaking, the internal combustion motor, has been known to us for many years. From the earliest to the most modern engine, a fundamental principle is applicable, namely, the combustion of the fuel in a closed cylinder delivering its energy by virtue of the expansion of the products of combustion to a piston suitably connected to a rotating shaft.

Solid, liquid, and gaseous fuels have been used, the first-named with varying success, while engines using liquid and gaseous fuel have been eminently successful.

The Deisel engine is the leading exponent of the liquid fuel class. In it, one stroke of the piston draws in free air, which on the return of the piston is compressed to between 400 and 500 lbs. pressure, thus heating it to a correspondingly high temperature. At a precise moment, when the engine is about on centre, a small quantity of liquid fuel is injected by mechanical means into this hot compressed air, which is at a temperature sufficiently high to ignite it. The oil on burning raises the temperature of the air and burned gases, thereby increasing the pressure and delivering energy to the piston.

It might be supposed that as the terminal pressure due to compression is very high, the initial pressure of the burned gases would become dangerously so, but this is not the case since combustion only starts at the beginning of the stroke and continues for a definite period, which may be any portion of the stroke desired by timing the rate and quantity of fuel injected.

Indeed, so fundamental is this characteristic that this engine belongs to the class known as continuous combustion engines. The expansion line during combustion is above the adiabatic and approaches isothermal expansion, showing that combustion takes place while the piston is moving forward.

Speed control under varying loads is obtained by altering the quantity of oil injected, and, there being always sufficient air, combustion is almost perfect at all loads.

The Deisel engine under continuous running has a thermal efficiency of about 35% and under ideal conditions has, I believe, surpassed 40%.

The internal combustion motor on gaseous fuel has characteristics entirely different from those of the continuous combustion type. In it, an explosive mixture of air and gas is, in the four-stroke per cycle engine, aspirated by the forward movement of the piston, which on its return stroke compresses this mixture to a terminal pressure ranging approximately from 90 to 180 lbs. absolute, this pressure being determined by the character of gas used, to which reference will be made later.

Near the end of the compression stroke, at some precise moment, the mixture is ignited, usually by electrical means and combustion once started is so rapid that it is more in the nature of an explosion. Immediately following ignition the pressure rises, a maximum being reached before any perceptible motion of the piston takes place; then the hot burned gases expanding almost adiabatically deliver their energy to the piston. Thefourth stroke of the piston completes the cycle by expelling the burned gases at atmospheric pressure by simple displacement.

In the two-stroke per cycle engine the capacity in horse-power with given cylinder dimensions is much greater than in the four-stroke engine, because two idle strokes, namely, suction and scavenging, are eliminated by admitting previously compressed gas and air separately under a pressure of from 5 to 10 lbs., which simultaneously expels the burned gases and fills the cylinder with mixture immediately after the power stroke has been completed, and before the compression stroke begins.

Added complication and smaller cylinder in the two-stroke type, with greater simplicity and larger cylinder in the four-stroke, each have their advocates and claims to attention.

Natural gas, bench gas, oil gas, blast furnace gas, and many other gases, all make excellent power fuels, but for the purposes of this paper, I shall confine my remarks to producer gas. Please note the distinction between simple producer gas, the product where air alone is the oxidizing medium, the use of which is now practically obsolete, and producer gas proper where water and air both supply the necessary oxygen. A gas producer is essentially an air-tight shell lined with some heat resisting material; means for supporting solid, incandescent fuel; for admission of air and steam in proper proportion either above or below this fuel; for removing the gas as formed, and for charging fresh fuel without admission of air. It resembles very much an iron blast furnace on a small scale, if the blast of the latter be considered as moisture laden air, and the charge entirely carbonaceous.

Two distinct types of producer are in commercial use, namely: the suction type and the pressure type. They are, however, practically identical in action, the former deriving its draft from the suction of the moving piston of the four-stroke per cycle

engine, while the latter is operated by forced draft. With the exception of this difference the description of the pressure producer, which follows, answers for the suction type as well.

Supposing a producer to have an initial charge of incandescent coal of considerable thickness, through which air is blown; carbon dioxide is formed at the grate and this is reduced to monoxide in its passage through the overlying hot coal, the process as a whole evolving heat.

If now the air blast be changed to a steam blast, the latter will be decomposed into hydrogen and oxygen, the oxygen uniting with the carbon to form carbon dioxide, which is as before reduced to carbon monoxide, and this reaction as a whole being endothermic, the temperature of the incandescent fuel is reduced, till finally decomposition stops. The hydrogen liberated in the above reaction passes off as a constituent of the gas. In both the above cases 50% or more of inert nitrogen remains in the gas.

The first of these reactions makes simple producer gas; the second makes what is known as water gas.

If now steam and air in proper proportion be blown through the producer, these two reactions take place simultaneously and one of them being exothermic, the other endothermic, i.e., opposed to one another, the temperature of the producer can be controlled to a nicety by varying the blast. The product from these reactions is producer gas proper.

The functions of the steam are many; indeed its use in the producer may be considered as of vital importance. It increases the efficiency of the producer by absorbing a large part of the sensible heat of the gas necessary for its decomposition, in this way recovering heat which would otherwise be lost. It increases the calorific power of the gas by furnishing a part of the oxygen for oxidizing the carbon to CO, thus decreasing the amount of inert nitrogen in the gas which would result if air alone were used, and also by introducing hydrogen with its high heat value; while mechanically it is distinctly advantageous in keeping the producer at a proper temperature and lessening the formation of clinker.

The manner of introducing the blast to the producer is extremely simple, being almost if not invariably by means of a steam jet under pressure drawing air with it and forcing the mixture through the fuel.

An analysis of a typical producer gas from bituminous fuel gives:—

	Per cent.
Carbon monoxide	23.
Hydrogen	8.5
Nitrogen	60.
Carbon dioxide	5.
Marsh gas, olefiant gas and oxygen	3.

Such a gas has a heating value of from 130 to 140 B.t.u. per foot and requires for combustion about equal volumes of air so that a foot of mixture has a calorific value of, approximately, 65 to 70 B.t.u.

Producer gas from a good grade of anthracite, coke, or other carbonaceous fuel low in volatile matter, after cooling and washing out any solid in suspension, is at once ready for use in the engine cylinder without further preparation, and on such fuel a gas power plant is extremely simple. When anthracite is used it is generally pea size, but even a finer meshed coal answers admirably.

With bituminous coals and fuels high in volatile products, for example, wood, imperfectly burned charcoal, lignites, etc., auxiliary apparatus is necessary to cleanse the gas and remove the condensible tarry vapors before it can be used in the cylinder where the presence of such constituents would in a short time clog up and interfere with the operation of the valves. A great deal of work has been expended in attempting to design a producer which will break up these vapors into fixed gases, one method being to pass the vapor-laden gas through incandescent coal. This method has had a certain measure of success in practice, but it introduces other difficulties, the most persistent of which is the formation of soot which, though not nearly so objectionable as the tarry matter, is still very undesirable.

In expensive plants, as for example those using the Mond process, the condensible vapors are extracted and manufactured into by-products, but this is working around rather than eliminating the obstacle. Furthermore such recovery apparatus is expensive, undesirable, and commercially impracticable at a mine. The final solution of the difficulty must lie in a producer which will destroy these volatile products and possibly reduce

them into a useful fixed gas. The advent of such a machine will eliminate the only obstacle in the way of an almost universal use of gas power, for stationary work at least.

With some of the most advanced men of science in the world working on the subject, is it too much to expect that the near future will see a producer capable of completely gasifying all the carbonaceous matter, both fixed and volatile, of even those fuels so low in combustible constituents as to render them almost valueless for steaming purposes?

In my opening remarks on engines using gaseous fuels I referred to different degrees of pre-ignition compression determined by the character of the gas used. I shall now recur to this, and for the sake of brevity shall make certain statements founded on sound theoretical considerations and observed facts, trusting they will be accepted as truths.

Natural gas with a heat value of roughly 1,000 B.t.u. requires for perfect combustion about 10 times its own volume of air, whence one cubic foot of mixture has a heat value of approximately 90 B.t.u.

Producer gas with a heat value of 140 B.t.u. requires about equal volumes of air for combustion, whence 1 cubic foot of mixture has a thermal capacity of approximately 70 B.t.u. per foot.

At the same speed and with identical degrees of compression engines of equal horse-power on these two gases would require cylinder volumes in nearly inverse proportion to the heat value of their respective mixtures.

On the other hand, because of the lesser inflammability of producer gas, its mixture can be compressed to a much higher pressure than a natural gas mixture. This increases the economy and by increasing the mean effective pressure on the piston the cylinder volumes are not in inverse ratio to the values of the different mixtures.

In practice, the area of piston of an engine on natural gas requires to be increased from 10 to 20% for use on producer gas, other things except compression being equal. In this regard the added economy of higher compression more than offsets the higher cost of cylinder.

The reason I take these two gases for an example is because they are nearly at extreme ends of the scale in their properties.

A practical example of varying compression on different gases is seen in the plants of the California Gas & Power Company, and the National Tube Company at McKeesport. In the former 600 B.t.u. gas is compressed to 95 lbs. absolute while the latter operates on blast furnace gas of 80 to 90 B.t.u., and compression is carried to 180 lbs. absolute—just double the former.

If the gas engine is as economical as its advocates claim it to be, why has it not been more rapidly adopted by engineers and manufacturers requiring power in large or small quantities?

This is a very pertinent question which if put to a steam engine supporter would be answered by the one word, unreliable. If an answer is had from the gas engine builder it would probably take a volume to hold it. In fact both answers must be qualified by a proper consideration of the facts and some knowledge of the past history of the gas engine.

Until quite recently, the gas engine was undoubtedly a most erratic machine. Sometimes it would run beautifully for days and days, stop when wanted to, and start up with ease at a moment's notice. At other times it would balk and without apparent cause refuse to run no matter how much it might be coaxed. Again it would continue to run apparently without fuel or ignition of any kind and it was even necessary sometimes to apply a brake to stop it. It was nearly impossible to predict even approximately what would happen next, and the so-called experts themselves were, more often than not, as far at sea as the laymen.

This condition of affairs persisted in the face of many changes, miscalled improvements, long enough to thoroughly convince everyone concerned that the gas engine was a failure, each failure being heralded far and wide by the steam men, and carefully tabulated and used as an argument against gas power by salesmen with steam apparatus.

This series of unsatisfactory plants could not but have its effect. A burned child fears fire, and the purchaser of a gas plant, having relegated it to the scrap heap and substituting steam, was thereafter somewhat candid in his expression of opinion when approached by the gas engine salesmen.

The causes of this antagonism were mainly two: First, the gas engine builder himself had a very hazy idea of what actually took place in the gas engine cylinder and, moreover, was usually without the means, either mentally or financially, of carrying out a thorough investigation; secondly, his anxiety to sell his wares in competition with the steam builder, with the latter's multitude of standard designs and low building costs, necessitated his entering the market with an incomplete and little understood machine, guaranteeing definite results, no matter what the conditions, on the strength of a few testing floor data.

It is surprising that the gas engine has been able to exist at all through such, for it, strenuous times, and the fact that it is making any advances, surely indicates that it must have certain inherent advantages over steam.

Again, with conditions that would in time have demonstrated the gas engine a commercial success, had the operators been versed in a few fundamental principles pertaining to it, the operator was usually a man whose experience had been altogether along steam lines: hence the majority of gas plants were doomed to failure from the signing of the contract between builder and purchaser.

Steam practice demands a specially designed engine for each class of work. Marine engines, mill engines, high-speed engines, condensing and non-condensing, simple and compound engines, traction engines and locomotives, all differ from each other in many salient points; even an engine for driving alternators may differ very materially from one for driving direct-current machinery.

Such a comprehensive series of designs was arrived at only after many years of work, and against this the gas engine builder had to pit a single fundamental cylinder with but a few years of experience and no special design beyond the fact that an engine was either an automobile engine, which is beyond the sphere of this paper, or a stationary engine operating on illuminating gas. Is it any wonder, then, that there have been many failures recorded against the gas engine?

But those days are gone, and the gas engine builder is beginning to specialize his designs, and with a constantly increasing and more exact knowledge of the several events which occur in the gas engine cylinder, these designs become more and more special.

Even to-day a large modern twin tandem gas engine is as different in appearance and mechanism from the smaller units of say 250 horse-power or less, as a modern marine leviathan is from the steam winch on deck.

The lesson has indeed been a costly one, but it has on the whole reacted for the common good, by forcing to the wall a nondescript class of builders and leaving the field clear to those men better fitted to cope with the problem.

These remarks might be construed as excuses rather than legitimate reasons for the failure of the gas engines in the past; but modern gas engineering results will, I think, substantiate them.

I may here call attention to the Indianna Steel Company's plant at Gary, a description of which is to be had in the *Engineering and Mining Journal* of December 26th. This plant operates on blast furnace gas and consists of 16 twin tandem blowing engines, cylinders 42 x 54, of 2,500 horse-power each. The power house contains 17 engines rated at 4,000 horse-power each driving one alternating or direct-current generator. The total capacity of the plant is 108,000 horse-power and the 4,000 horse-power engines are capable of a continuous overload of 30%. Since this is, I believe, the largest engine plant in the world, it speaks eloquently of the progress of the gas engine.

It must be apparent to even the casual observer that such confidence in gas power as is here shown by men responsible for a plant of such magnitude, men foremost respectively in the ranks of manufacturing, engineering and science, is strong presumption of their belief at least in the reliability of the gas engine.

Many instances can be cited showing by continuous and uninterrupted service for months at a time that the gas engine built for the conditions it must meet is in every case as reliable as steam.

The economy in fuel and water of the gas engine is so marked and so well known that I shall not refer to it more than to say that the long sought but never realized expression of "1 horse-power for 1 hour on 1 lb. of coal" for steam, has been surpassed by many gas engines.

I shall conclude this paper with a few notes on the probable future expansion of the gas engine, and its practical application to mining. I quote from a recent issue of *Power*:—

"A Complete-expansion Gas Engine."

"The typical internal-combustion engine of to-day discharges its exhaust gases at 20 to 40 lbs. above atmospheric pressure, and the two-stroke-cycle engine continues to take its charge in brief gulps and simultaneously to discharge its burned gases in almost equally brief snorts.

"An English engineer has risen to the occasion and proposed a construction and method of operation which appear to provide a practical elimination of the drawbacks mentioned in the preceding paragraph. In a paper read recently before the Institution of Civil Engineers, of Great Britain, James T. Milton proposed an engine using the two-stroke cycle, but in order to enhance the efficiency and increase the output per piston stroke, he suggested that *all* compression be done in air and gas compressors; that the engine be built with the smallest possible mechanical clearance; that the compressed air and gas be admitted separately during a small part of the piston stroke, the supply then cut off, and, simultaneously, the mixture in the cylinder ignited.

"The proposition is a most interesting one, even from the standpoint of the land gas engineer. The compression pressure could be made anything one chooses to design the engine for without liability to pre-ignition; expansion could be carried down to 15 or 16 lbs. absolute by adjusting the cut-off to that end; one design of engine could take any kind of fuel with no change in design beyond adding a sprayer and using a small pump instead of a compressor when oil is the fuel; a full stroke of the piston would be available for expelling the burned gases, although using the two-stroke cycle; the expulsion of burned gases would be almost complete, because of the small clearance, so that the fresh charge would not be greatly contaminated.

"Of course there are many details to be worked out. It is essential, for example, to mention the most obvious points, that the air and gas must not be allowed to mix outside the cylinders, that ignition should actually occur at the exact moment when the incoming fluid is shut off, and that expansion should not be carried appreciably below atmospheric pressure even at the lightest loads. But in the light of gas engine history thus far made there seems to be no grave difficulty in the way of applying

Mr. Milton's suggestion to both land and marine service, and there are certainly many advantages embodied in the plan. Dugald Clerk made tentative experiments along the same line many years ago, but he unfortunately compressed the mixture of air and gas in a single pump, with results that could easily be predicted nowadays but were not so obvious then."

Here we have the means for making an engine self starting by the energy of the compressed air and gas in a manner similar to an ordinary steam engine. Or a charge being admitted while the engine is at rest is in prime condition to be ignited, constituting in reality a self starting engine, capable of as nice control as is the long stroke steam hoist.

The idea of using gas and air under pressure appealed to me very strongly several years ago and I even went so far as to design a motion to start and run the engine from one lever, an essential for large hoists. On this I was granted Canadian patent, but foreign patents were unobtainable since several salient features were separately covered by others. I am firmly convinced, however, that the near future will see a commercially successful self-starting gas engine somewhat along these lines; in fact gas engineering literature shows a tendency to expansion in this direction. This in time will possibly be followed by the gas turbine, much as the steam engine has been the forerunner of the steam turbine, which latter is in the opinion of many engineers but a transition period between steam power and gas power.

The application of gas power to our own special conditions presents no great difficulty. For air compression the substitution of gas cylinders for the present steam cylinders is little more than a question of design with a due consideration of the different stresses resulting from such change. Gas-driven generators for driving scattered units with motors are feasible, practicable, and economical, whereas for hoisting, direct-current series motors or induction motors are readily applicable and have splendid characteristics for such work.

Such an arrangement would be a natural outcome for geared hoists when simplicity is of importance; indeed we must content ourselves for the present with electric drive from gas-driven generators until the advent of a self-starting-under-load gas hoist.

The future of the gas engine is assured beyond doubt, and it rests with us as to whether we shall or shall not reap some benefits from the use of a prime mover which will do as much work on 1 lb. of fuel as we now obtain from 5 to 10 lbs. by means of steam.

DISCUSSION.

Mr. R. W. Hinton.—Mr. Burnett in his extremely interesting paper has drawn the attention of the mining men of this district to a new possibility of reducing mining and smelting costs, and this, of course, is of very special interest to them. He has done this too in a most conservative manner. Where the usual radical reformer overestimates the advantages and minimizes the cost of the changes he advocates, Mr. Burnett appears to me to have erred, if at all, on the side of moderation.

For instance, he claims for the engine running on producer gas from anthracite an efficiency of 1 h.p. hour for 1 lb. of coal, while as a matter of fact very many plants are running to-day on $\frac{7}{8}$ of a pound, and even this amount is being gradually reduced. A further reduction in cost, if not in quantity of fuel, which may appeal to the smelter manager, is due to the fact that for producer purposes 1 lb. of coke breeze is just as good as 1 lb. of coal. If these coke fines are used in the smelter furnace a considerable amount of the fuel value goes into the flue, and it is doubtful if the cost of briquetting an extra quantity of flue dust is paid for by the recovery of the fuel.

Again, I cannot quite agree with his summary dismissal of the bituminous coal producer, of the Mond type, as impracticable for mining purposes. Undoubtedly the anthracite or coke producer is much better suited to the small plant; but there is much to be said in favour of the soft coal plant for larger powers. From a purely local point of view, Crow's Nest coal is much cheaper than either coke or anthracite, and for a larger plant it is not an expensive process to remove the tar and other undesirable products; indeed in this district where a large sum is spent annually on fertilizers, the by-products could probably be made to pay a considerable proportion of the fuel bill.

There is one point on which I should like to touch in this connection, and that is the advantage of the producer gas plant for mines in places where the available supply of cordwood has run out, and the management has to depend on steam generated from coal. To my own knowledge many small plants take as much as 8 or even 10 pounds of coal for each h.p. actually used—this is of course due partly to uneconomical types of engine, and to varying loads, and also to the excessive "stand by" cost of a coal plant, *i.e.*, the amount of fuel used to merely keep up steam or bank the fires.

Now with a gas plant, especially with a suction type of producer, the consumption of fuel corresponds almost exactly to the h.p. used, and the fuel required to bank a 100 h.p. plant over night would not exceed 100 lbs.

Another difficulty in the mining camp is the obtaining of firemen who can keep up steam—every hour with low steam meaning a considerable decrease in the output of the mine, with no corresponding decrease in the labour bill. This difficulty is entirely overcome in the gas producer, where the firing is practically automatic, and the attention to the producer so simple that it is within the powers of the most unskilled labourer.

At the close of his paper Mr. Burnett spoke of the possibility of using compressed air and gas for a self starting engine. This is already an accomplished fact—one make of gas engines, at least, being provided (in its larger sizes) with a small compressor, by which a tank is charged with compressed air before shutting down and this charge stored for the purpose of restarting. In the usual mining plant, moreover, there is almost always an available supply of compressed air which can be used for this purpose.

Mr. S. S. FOWLER:—Mr. Burnett's "few notes" appear to me to form a thesis of distinctly high grade.

In a country so blessed with an abundance of cheaply developed water-power, as south-eastern British Columbia is, few engineers may be called upon to follow out the suggestions made by Mr. Burnett; but I happen to know of several instances in which a more extensive and intimate knowledge of the uses and operation of internal combustion motors might have resulted in much less capital expenditure or less working costs or both. In most of these instances, it is true, the prospective scale of operations would

not have justified a producer plant—much less, indeed, one for the generation and transmission of hydro-electric power—but liquid fuel might have been and probably, in the future, will be more extensively used when the internal combustion motor is more nearly perfected and its advantages appreciated.

I may cite one of the instances which I have just alluded to. The owners of a slightly developed mine doubtless had an exalted notion of its future value and proceeded with its equipment accordingly. If advised at all they were so badly advised as to have installed a compressor of about "two-drill" capacity at an altitude of something over 6,000 feet, to be driven by steam from a water-tube boiler of first-class make. The boiler setting was necessarily in brick which were purchased in a prairie town, hauled by railway 150 miles, thence by steamer 85 miles and then with the other equipment 30 miles by wagon road to their present resting place—still 7,000 feet from and 1,000 feet lower than the mine. I am certain that those bricks are still blushing.

Without going into details, is it not evident that many thousands of dollars in first cost, to say nothing of many hundreds in operating this plant during the one year of its usefulness, might have been saved? The mistake fairly may be ascribed to ignorance of the merits of even a "bucking" gasoline engine, and if Mr. Burnett's paper finally dispels some of that ignorance it will have been of much use.

Aside, however, from the merits or demerits of the sundry prime movers, I think we are to be congratulated on the privilege of listening to a paper such as this of Mr. Burnett's—a paper well constructed, logical, suggestive and one that can be listened to easily—as compared with papers of the descriptive class, however interesting and practical. I desire to express my appreciation of it.

SOME POSSIBLE CHEMICAL CHANGES IN THE FORMATION OF COAL.

By D. B. DOWLING, Geological Survey, Ottawa.

(Annual Meeting, Montreal, March, 1909).

In the consideration of the changes that have taken place in the formation of coal from vegetable remains in the form of peat, it is necessary to examine the effects that the application of either heat or pressure has upon such matter. For, to a combination of the two, we owe, we believe, the substances called coal.

Heat applied without pressure has been the subject of experiments; and, although wood was the subject in the experiment, this will serve very well upon which to base some conclusions. The tabulated results of the analysis of the product as the temperature was increased are quoted below; but a diagram in which these values are shown graphically is easier understood.

The analysis of the wood is plotted on a horizontal line. The vertical co-ordinates are to the same scale and the increase in percentage of carbon is shown by intersections of a straight line at 45° to the horizontal. At any point in the diagram a horizontal line will give the analysis. The loss of carbon is in the same manner shown at the end of the diagram. The temperatures used are indicated at the end.

The history thus indicated seems to point to the loss first—up to a temperature of 392° Fah.—of hydrogen and carbon, which, we would naturally conclude, implied the formation of illuminating gases. After the hydrogen was reduced to a percentage below 5, oxygen combined with carbon and from this point the production of CO_2 and C_nH_m continued in varying proportions, until there was left only about 30 per cent. of the carbon, which seemed from the diagram to withstand the increase in temperature without loss up to near 2372° F. The matter driven

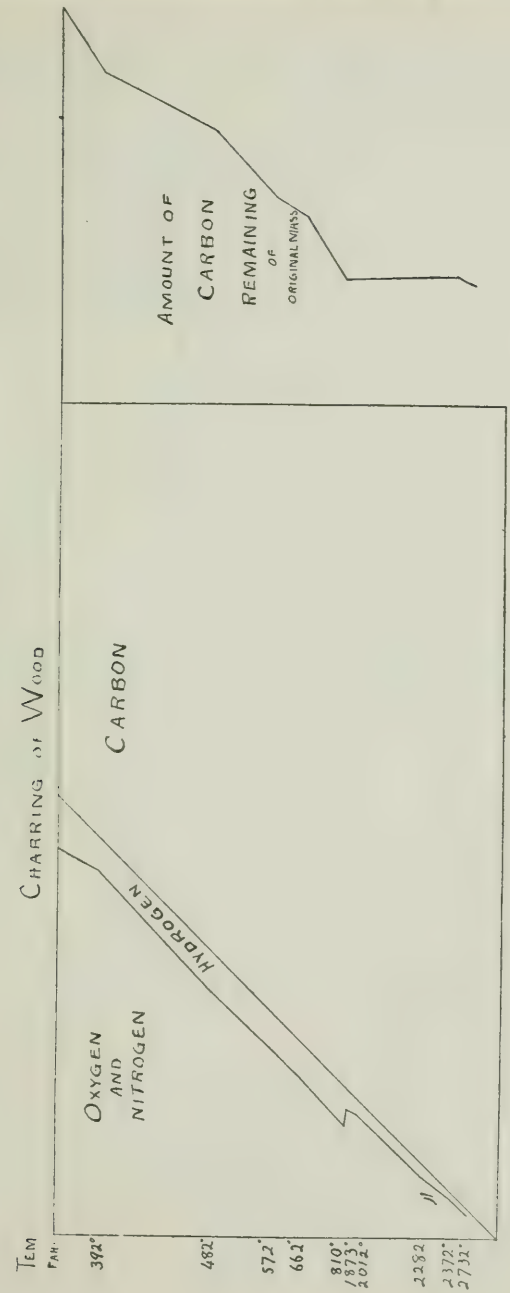

TEM
FAH.
392°
482°
572°
662°
810°
1873°
2012°
2282
2372°
2732°
CHARRING OF WOOD
OXYGEN AND NITROGEN
HYDROGEN
CARBON
AMOUNT OF CARBON REMAINING OF ORIGINAL MASS

DIAGRAM No. 1.

off then must have been oxygen, hydrogen and nitrogen, either as free gases or combined in such forms as water vapour or ammonia.

CHARRING OF WOOD.*

EXPERIMENTS BY M. VIOLETTE.

Temperature Fahrenheit	Composition of the Solid.				Carbon for a given weight of wood
	Carbon	Hydrogen	Oxygen, Nitrogen and loss	Ash	
302°	47.51	6.12	46.29	0.08	47.51
392°	51.82	3.99	43.98	0.23	39.88
482°	65.59	4.81	28.97	0.63	32.98
572°	73.24	4.25	21.96	0.57	24.61
662°	76.64	4.14	18.44	0.61	22.42
810°	81.64	4.96	15.24	1.61	15.40
1873°	81.97	2.30	14.15	1.60	15.30
2012°	83.29	1.70	13.79	1.22	15.32
2282°	88.14	1.42	9.26	1.20	15.80
2372°	90.81	1.58	6.49	1.15	15.85
2732°	94.75	0.74	3.84	0.66	15.36

The hydrogen percentage at any point, after the application of heat falls below that found in lignites or bituminous coals, so that, if we assume that to have made coal of this substance, some influence restraining the loss of hydrogen must have been introduced. This we can, therefore, assume to have been pressure and its application at the beginning would first be felt in the prevention of the formation of the heavy hydro-carbon gases, and, consequently, possibly also a decrease in the waste of carbon.

Experiments with pressure alone do not give results, since great periods of time are required; but when supplemented by heat, there is evidence that there is a chemical change made by which the increased percentage of carbon is attained with very little actual loss of carbon.

Without considering the cause, we may discuss the compounds that are given off in the distillation and their effect on the resultant chemical analysis. As a basis for comparison it is advantageous to have a diagram illustrating an average series of analyses of coals. The variations from the hydrogen and nitrogen percentages give different qualities, which will not be discussed at length in

*From Clarke's Rules, Tables and Data for Mechanical Engineers.

the present paper, but on Diagram II the coal analysis is indicated in dotted lines so as not to multiply diagrams unduly.

In this paper we take an analysis for peat and assume that from this the several gases are extracted and diagrams of the resulting theoretical analyses are plotted.

Extraction of Hydro-Carbon Compounds.

The effect of the extraction of any of these upon the analysis is to lower the percentage of carbon and use up the hydrogen. The extraction of CH_4 is illustrated in Diagram II.

Peat Analysis used for Diagrams.

Carbon	50.00
Hydrogen	7.00
Oxygen	42.06
Nitrogen	.94
	100.00

The extraction of CH_4 analysis for peat from the rapidly diminishes the hydrogen and carbon percentage and when hydrogen is all gone the above analysis theoretically becomes: –

Carbon	40.18
Hydrogen	0.00
Oxygen	58.42
Nitrogen	1.40
	100.00

At this point 28 per cent. of the mass has been driven off carrying 21 per cent. as carbon. This amounts to 42 per cent. of the original carbon.

Carbon and Oxygen.

Whatever combination is extracted, the effect on the analysis is almost the opposite to that for hydro-carbons; that is the carbon percentage is increased as well as that for hydrogen, while the oxygen is decreased. In diagram No. III the peat analysis

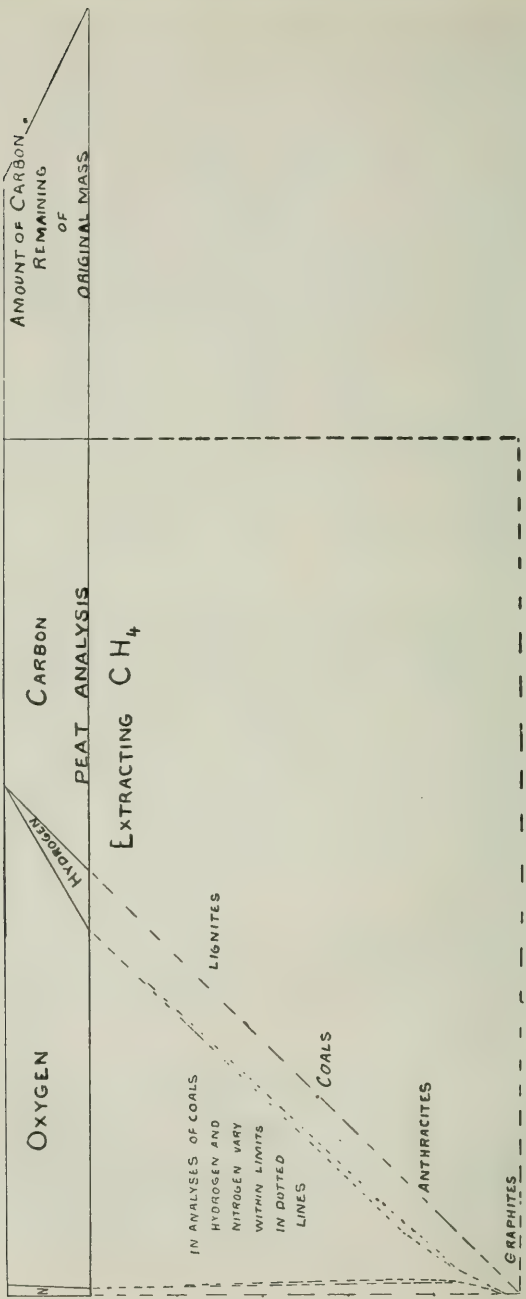

AMOUNT OF CARBON REMAINING OF ORIGINAL MASS
CARBON
OXYGEN
HYDROGEN
PEAT ANALYSIS
EXTRACTING CH_4
LIGNITES
COALS
ANTHRACITES
GRAPHITES
IN ANALYSES OF COALS HYDROGEN AND NITROGEN VARY WITHIN LIMITS IN DOTTED LINES

DIAGRAM No. 2.

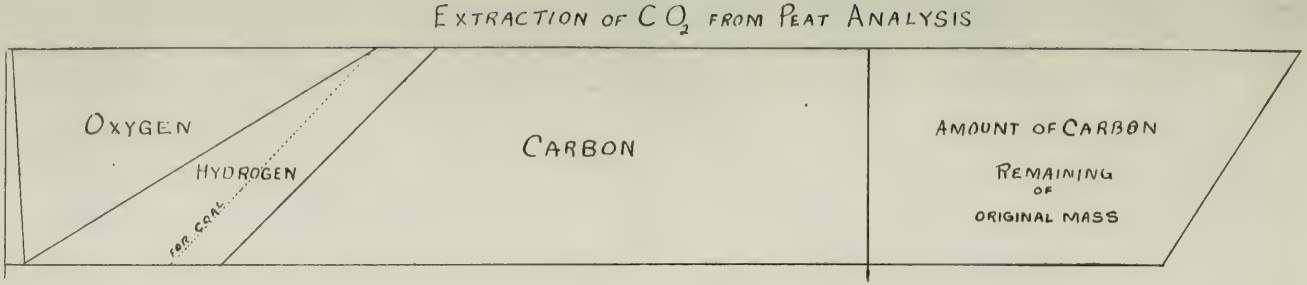


DIAGRAM NO. 3.

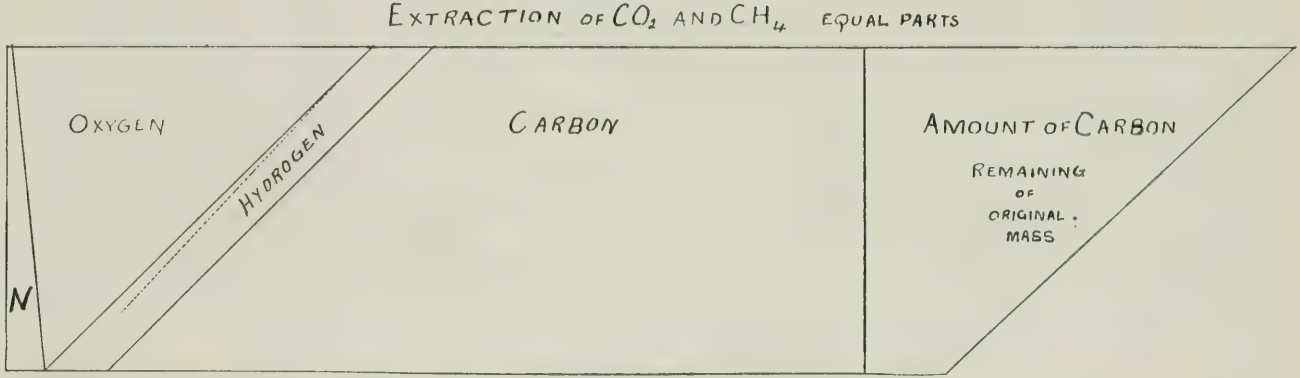


DIAGRAM NO. 4.

considered in the last is also used for the basis and with the loss of all the oxygen the peat analysis theoretically becomes:—

Carbon	74.98
Hydrogen	22.56
Oxygen	00.00
Nitrogen	2.46
	100.00

The extraction or loss of CO_2 and CH_4 have thus opposite effects upon the analysis; and we may almost assume that we could by varying the amounts of each extracted produce an analysis that would be similar to that for coal.

First, if we take CO_2 2 parts and CH_4 5 parts from the above analysis the carbon percentage remains constant; but, if we increase the portion of CO_2 extracted, there is an increase in the carbon percentage.

Equal parts of CO_2 and CH_4 taken from the peat analysis, produce a theoretical analysis which is higher in hydrogen than an average coal analysis but within the limits. The nitrogen is increased and may be assumed as not disturbing the general analysis if it is reduced in the production of ammonia. Diagram IV illustrates not only this series of analyses but the theoretical loss of carbon from the original mass.

Attempts at a theoretical combination which would, if extracted as gas from the mass, produce a series of analyses closely following that for coal is plotted in Diagram No. V. The first combination is CO_2 thirty-six parts, CH_4 forty-two parts and NH_3 one part.

The theoretical analysis after these gases have been extracted to the point when oxygen is about used up would be:—

Carbon	94.65
Hydrogen	3.66
Oxygen	0.37
Nitrogen	1.32

This result is possibly too low in hydrogen through the lignites and bituminous coals, but is approximately correct for the hydrogen in anthracites.

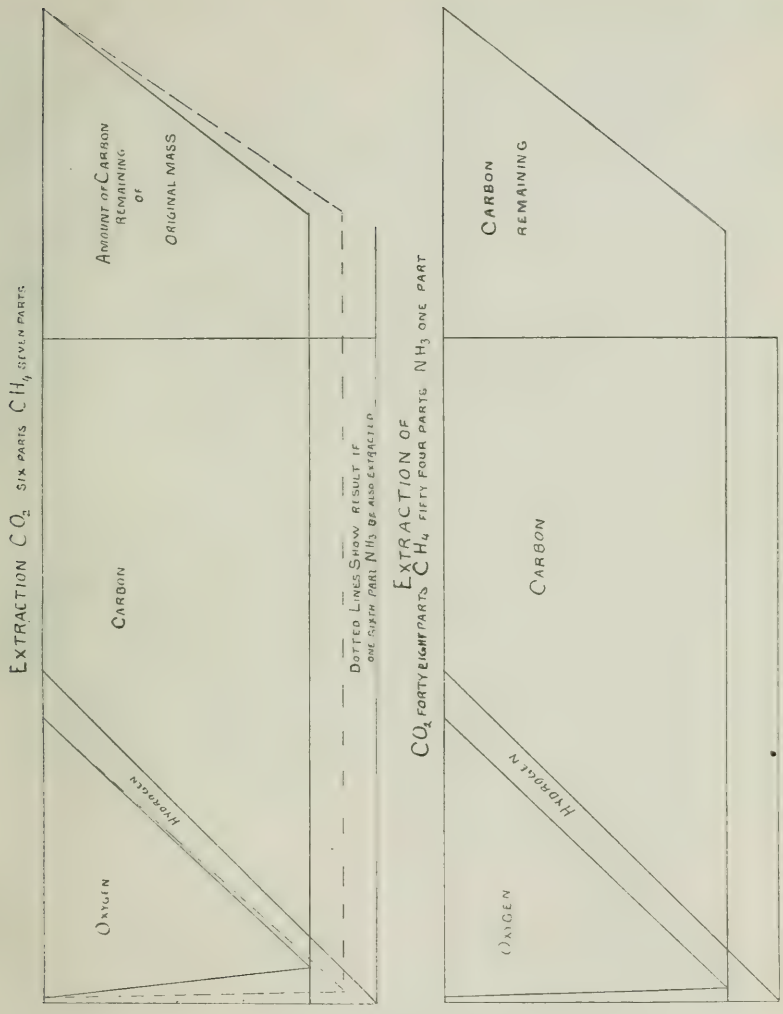


DIAGRAM NO. 5.

A better approximation would be the extraction of CO_2 eight parts, CH_4 nine parts and $\frac{1}{6}$ part NH_3. We then get a formula for reducing the peat analysis through the lignites and bituminous coals that would give nearly parallel values to those

in actual coal analyses. At the maximum percentage for carbon, that is when the oxygen is used up, the analysis stands as:—

Carbon	92.13
Hydrogen	5.48
Nitrogen	2.38

giving a diagram which is a very fair copy of the coal analyses, but of the original carbon there has been wasted 66 per cent., and 84 per cent. of the original weight of the mass is absent.

If the ash is not forced off with the gases distilled, its percentage has been increased seven times.

If we accept the above as the waste in forming coal, we are burdened with accounting for the loss of carbon, which would be twice the amount in a coal seam. We would also require to account for the disappearance of a great amount of ash, since the percentage in average coal is not twice that of fairly pure peat, whereas if altered to coal by the above distillation the ash should be seven times that of peat.

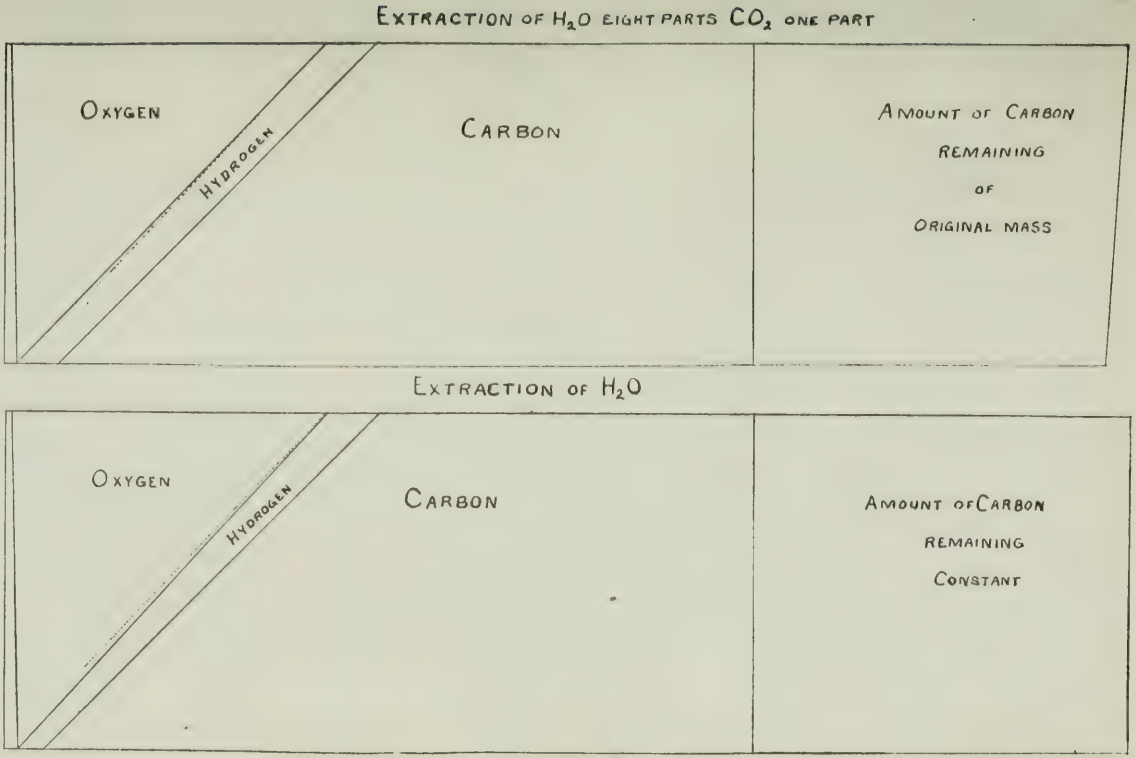
COMBINATIONS OF OXYGEN AND HYDROGEN.

So far we have considered hydrogen in combination with carbon, but the combination with oxygen seems more important, since it is definitely announced that experiments on peat prove that under pressure and heat no gas is formed in raising the carbon percentage, and that water is the only substance extracted. With this hypothesis it is worth while making further investigations, and in conformity with the general scheme here adopted, Diagram No. VI has been plotted. The basis for the diagram is the following analysis of partly dry peat:—

Carbon	41.8
Hydrogen	7.3
Nitrogen	0.8
Oxygen	46.9
Ash	3.1
	100

Calculated for ash free state this becomes:—

Carbon	43.20
Hydrogen	7.53
Oxygen	48.45
Nitrogen	.82
	100.00



DIAGRAMS NOS. 6 AND 7.

EXPANDED PEAT ANALYSIS BY EXTRACTING H_2O.

Carbon . . .	43.20	50.00	60.00	63.82	68.08	70.00	73.63	77.00	80.00	83.69	90.00	
Hydrogen . .	7.54	7.00	6.18	5.86	5.52	5.36	5.06	4.78	4.54	4.24	3.72	
Nitrogen . . .	.82	.94	1.13	1.20	1.21	1.32	1.38	1.45	1.49	1.55	1.67	
Oxygen	48.45	42.06	32.69	29.12	25.19	23.32	19.93	16.77	13.97	10.52	4.61	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

If the hypothesis that water was the only product were correct, we would, no doubt, find coal analyses that would be similar to some of the above. Many are similar, and, in fact, so like those above that at first glance we might be content to accept this theory as conclusive.

To follow the comparisons more closely, a few of the expanded peat analyses have been calculated to the same carbon percentage

as is given in some of our coals and the published analyses of the manufactured peat coals. For these the comparisons are as follows:—

	Peat with H_2O extracted.	Comparison	Analysis	
Carbon.....	63.82	0	63.82	Peat Coal briquette
Hydrogen...	5.86	+1.15	7.01	made under pressure
Nitrogen....	1.20	.03	1.23	and heat.
Oxygen.....	29.12	−1.18	27.94	
	100		100	
Carbon.....	68.08		68.08	Peat Coal briquette
Hydrogen...	5.52	+ .47	5.99	made under pressure
Nitrogen....	1.21	− .08	1.13	and heat.
Oxygen.....	25.19	− .39	24.80	
	100.00		100.00	
Carbon.....	73.63		73.63	
Hydrogen...	5.06	+86	5.92	Lignite from Crockett,
Nitrogen....	1.38	—04	1.34	Texas.
Oxygen.....	19.93	—82	19.11	
	100.00		100.00	
Carbon.....	77.00	—.09	76.91	Lignite from Simpson
Hydrogen...	4.78	+.54	5.32	mine, Lafayette, Col-
Nitrogen....	1.45	+.08	1.53	orado.
Oxygen.....	16.77	—.53	16.24	
	100.00		100.00	
Carbon.....	80.00		80.45	
Hydrogen...	4.54		5.41	Coal from Wellington
Nitrogen....	1.49		14.14	mine, Nanaimo, B.C.
Oxygen.....	13.97			
	100.00		100.00	
Carbon.....	83.69		83.69	
Hydrogen...	4.24	+1.39	5.63	Coal from Hartshorne,
Nitrogen....	1.55	+ .47	2.02	Indian Territory.
Oxygen.....	10.52	—1.86	8.66	
			100.00	
Carbon.....	91.00	+.10	91.10	
Hydrogen...	3.64	+.89	4.53	Coal from Windber,
Nitrogen....	1.69	—.18	1.51	Penn.
Oxygen.....	3.67	—.81	2.86	
	100.00		100.00	

We might say that these analyses, with slight variation, would pass for the coals with which they are compared; but it is strange that in all the oxygen is in excess of that in the coal, and the hydrogen is too low. The nitrogen may be taken as being very nearly

right. This suggests that that if it is necessary to raise the hydrogen and lower the oxygen, a compound with carbon and oxygen would have to be formed. This is best obtained in CO_2, a gas whose solubility is high and is increased under pressure.

The only combination whose extraction raises the percentage of hydrogen, we find in Diagram III, the extraction of CO_2. If then we modify the last diagram by assuming that under pressure the water would carry away in solution CO_2, then we have a means of raising the hydrogen percentage; and in Diagram VII we have assumed a combination of H_2O and CO_2 in proportions of 8 to 1 as being the substances extracted, and we get a diagram which follows very nearly the coal analysis, with the nitrogen about the right percentage, so that very little ammonia need be formed. We have then a second formula for the production of coal, and one in which the loss of carbon has been kept down to a minimum, being only 6% of the original carbon.

TWO FORMULAE FOR MAKING COAL.

1. Extraction of CO_2, thirty to forty parts.
   " CH_4, twenty to thirty parts.
   " NH_3, one part.
2. Extraction of H_2O, seven to nine parts.
   " CO_2, one part.

The first entails a loss of 60% carbon.

The second entails a loss of 6% carbon.

The first in loss of carbon resembles very much the diagram obtained by heat (Diagram I) with little pressure.

The second follows the results of experiments on peat, using heavy pressures with heat. So that we conclude that coal could be formed by either of the above theoretical extractions of material from peat; but since the second, the water extraction, requires apparently great pressure, it is probable that both processes proceeded concurrently. In the initial stage the decomposition, no doubt, was hastened by micro-organisms which are everywhere present, and many of these by their growth, especially the ferments, liberate from the mass carbon dioxide. If then the presence of microbes in the decaying vegetable matter is of value it is distinctly owing to their being the cause of the liberation of

CO_2 and the consequent increase in the hydrogen percentage. The fermentation in the early stages of decay may account for the formation of peats which were afterward altered to fatty coals such as cannel and coking coals: or to be the formation of lean coal from peat which had not this chance for enrichment. The alteration of the peats during and after this initial period no doubt, produced marsh gas, ammonia and carbon dioxide; but as nature is not so generally wasteful, it seems probable that this waste was stopped by covering, and that the general change then went on by the extraction of water and CO_2. This is supposed to be a slow process, induced under pressure by moderate temperatures. Earth movements, whereby the temperature was raised, hastened the process; but should these movements lead to fractures as well as rise of temperatures the static pressure would be changed to load and hydrocarbons would then be given off. This then would indicate a rapid local alteration, and is possibly the final stage in the hardening of our bituminous coals into anthracite.

That the greater amount of the change in the formation of our coals is due to the slow process of water extraction, seems evident from the fact that the ash in the coals is not increased to a very much greater extent over that for vegetable matter than this theory would allow; and, secondly, that very few geologists will allow that the vegetable remains associated with the coals have lost a great percentage of their carbon.

Stability of Coals.

If we allow these two distinct methods of alteration in the formation of coal, they should develop in the product different characteristics. If, for example, we could have two coals of the same carbon content formed by each of these two methods, it would seem reasonable to suppose that the coal, which had lost in its formation much of its carbon along with other elements, would not have the same tendency to form gas and possibly also not be as easily coked. Its composition might be termed *stable*.

On the other hand, a coal whose atoms are combined under pressure and, mainly as the result of pressure, would, when released from load, be *unstable*, and its chief characteristics might be a tendency to give off gas and a tendency to coke when heated.

Should it be admitted, for this latter class, that there is a direct connection between carbon percentage and required pressure, then it follows that coal compounds formed under low pressures would be more stable than those whose formation required great pressures. Thus upon release from load, coals of low carbon content would not be likely to form gas such as lignites and low carbon bituminous, or those coals whose alteration was accomplished by heat and low pressure—among others anthracites.

In the same way coals formed under high static pressure would be distinctly unstable; and, among the bituminous coals, we find the higher grades containing up to 85% carbon to be distinctly gas producing in the mines.

If we infer that the higher the carbon content the greater the pressure required to produce it, we are possibly right except that the fracture limit is reached and, as before noted, the coal is altered by losing carbon, so that our theory of stability may be applied as a rule through the bituminous coals only.

That there is an increased tendency to throw off gas with the rise in carbon percentage is acknowledged; and when it has reached its maximum the coal might in some instances be classed almost with such unstable compounds as explosives. There are accounts of slight shocks producing "blow outs" of large dimensions in mines of the higher bituminous coals. This liberation of gas need not be considered as coming from pockets of compressed gas, but following much the same course as an explosion of dynamite which is simply the rapid rearrangement of atoms.

It would seem probable that the formation of gas was accompanied by a concurrent formation of a more stable coal compound and when the alteration was violent the stable coal was brought along with the gas as a dust.

Dust not formed in this way but from the operations of mining and handling the coal, should be considered more as a series of minute particles of unstable compound borne along by a small gas atmosphere of its own making and, therefore, not easily laid by sprinkling and only to be got rid of by ventilation. With this digression, the excuse for which is that the theory of the formation of coal by pressure seems to afford some explanation, one conclusion should be briefly touched before leaving the subject.

Utilization of Peat.

If coal has been formed in nature by the conservation of the carbon, experiments on the production of a high carbon fuel out of peat should aim to follow the methods of nature and if heat is applied, it should be under pressure as contrasted with the efforts to char the peat into a charcoal, since this latter entails a great loss of carbon and its only merit lies in the fact that the gases given off are utilized in supplying heat by their combustion for the process.

Analyses Plotted in Diagram No. 2.

1. Irish peat averages from Philipstown, Bog of Allen Ticknevin and upper Shannon, dry and free of ash.

Carbon	59.88
Hydrogen	6.00
Oxygen	32.32
Nitrogen	1.25

2. Outcrop coal seam in South Saskatchewan, 10 miles above Medicine Hat.

Carbon	72.26
Hydrogen	4.44
Oxygen and Nitrogen	23.30

3. Texas No. 1, near Crockett.

Carbon	73.63
Hydrogen	5.92
Oxygen	19.11
Nitrogen	1.34

4. Coal Banks, outcrops near Lethbridge.

Carbon	76.60
Hydrogen	5.04
Nitrogen and Oxygen	18.36

5. Simpson Mine, Layfayette, Col.

Carbon	76.91
Hydrogen	5.32
Oxygen	16.24
Nitrogen	1.53

6. Wellington Mine, Nanaimo, B.C.
   - Carbon 80.45
   - Hydrogen 5.41
   - Oxygen and Nitrogen 14.14

7. Henryetta, Indian Territory, Coal No. 1.
   - Carbon 83.31
   - Hydrogen 5.62
   - Oxygen 9.47
   - Nitrogen 1.52

8. Outcrop, Mill Creek, Alberta.
   - Carbon 83.65
   - Hydrogen 4.73
   - Oxygen and Nitrogen 11.62

9. Windber, Pennsylvania.
   - Carbon 91.09
   - Hydrogen 4.53
   - Oxygen 2.86
   - Nitrogen 1.51

10. Scranton, Pennsylvania.
    - Carbon 93.07
    - Hydrogen 3.19
    - Oxygen 2.77
    - Nitrogen ..... .99

11. Graphite, Grenville.
    - Carbon 98.56
    - Hydrogen 1.34

12. Graphitoid, Saxony.
    - Carbon 99.76
    - Hydrogen 0.24

13. Schungite, Russia.
    - Carbon 99.60
    - Hydrogen 0.40

DISCUSSION.

Mr. James M. Macoun (Ottawa):—Mr. President, there was one point in Mr. Dowling's paper that I think might be specially emphasized, and that is the concluding portion of the paper in which he enunciated his theory that what has been done in nature with regard to coal may be done artificially with heat and pressure; that is to say that peat may be transformed into coal by the application of heat as it has been done in nature through the lapse of a long period of time.

There are two large peat companies—the International Fuel and Power Co. and the Ekenberg Company which are actually producing coal from peat. At least that is the conclusion that must be drawn from the samples that have been examined. We are all familiar with peat fuel, but whether it is in the form of air dried briquettes or briquettes made from peat so finely ground up that we can hardly distinguish them from a solid substance—no matter how we may see them, they are still essentially peat; that is to say there has been no change of any kind and they are just as much peat as they were when the peat was taken wet from the bog. Whether they will succeed in producing peat coal commercially is something with which I think we need have nothing to do, but the fact remains that coal is now being produced artificially from peat, experimentally at least, and in a form in which if found in the field could not be distinguished from true coal. Personally I am very sorry indeed that there is not more opportunity to go further into the matter here, and I hope that at some other meeting of the Mining Institute, Mr. Dowling will elaborate that particular point in his paper with further data, in the hope that we may learn a good deal more than we know now as to how peat may be turned into coal.

Dr. J. B. Porter:—I should like to express a word of appreciation of the work that Mr. Dowling has done. He has been dealing with an extremely difficult and obscure subject. It happens that I have given a good deal of thought and study to the same matter and therefore I am in a position,—while I shall make no attempt to offer any theories of my own,—to say that

the more one learns of the difficulties of his subject, the greater is his appreciation of the work which Mr. Dowling has been doing in this line. As Mr. Coste pointed out a few moments ago, our coal and petroleum industry is of vast importance. The precious metal industry, although much more interesting to our membership at large, is a mere bagatelle as a world matter, as compared with the fuel industry, and anything that can be done looking to the development of either the coal or petroleum industry is of immense importance. I feel, and I am sure many others will feel, that with Mr. Dowling's assistance we have made a marked step in advance looking to the solution of this extremely obscure and difficult problem, not only of the origin of coal, but of the economic problem of the manufacture of coke which is a corollary of what Mr. Dowling is now working on.

MR. DOWLING:—If it is of interest to the meeting, I have a sample of coal made from peat by the Ettenburg process, but unfortunately I have no sample of the International Company's product.

PETROLEUMS AND COALS.

COMPARED IN THEIR NATURE, MODE OF OCCURRENCE AND ORIGIN.

By EUGENE COSTE, E.M., Toronto, Ont.

(Annual Meeting, Montreal, March, 1909)

There is found in nature a great variety of compounds of carbon, not only in the sedimentary strata of all ages, but also in crystalline rocks, in igneous and volcanic rocks, in seams and veins through all these, and even in meteorites.

All these carbon-compounds have been assigned by many geologists to the one and the same origin, namely:—an organic origin, from the decomposition or distillation of either animal or vegetable organic matter entombed in the strata, and they have all been grouped and classed in the one and the same series of compounds of carbon.

This organic origin cannot of course hold good for the natural carbon-compounds found in crystalline rocks, in igneous and volcanic rocks, in volcanic gaseous emanations, in metallic seams and veins where they are intimately associated with such minerals as quicksilver for instance, and also when they are found in meteorites. It has, therefore, always seemed to me that this idea of only one natural series of compounds of carbon with an organic origin, is so clearly at variance with so many well known geological facts and physical laws that I cannot cease to wonder how it is possible for such a huge error to have taken the firm root it has in the science of geology. In two papers which I read before this Institute, one nine years ago ([1]) and one six years ago ([2]), and in another paper which I read in 1904 before the American Institute of Mining Engineers ([3]), and before the Franklin Institute ([4]), I entered my strong protest against this fallacy. I

1. Journ. Can. Min. Inst., Vol. III, 1900, pp. 68–89.
2. Journ. Can. Min. Inst., Vol. VI, 1903, pp. 73–128.
3. Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 288–297.
4. Journ. Franklin Institute, Philadelphia, 1904.

pointed out in these papers the solfataric volcanic origin of the natural hydrocarbons or petroleums. Other geologists have also long ago given proofs of the inorganic origin of petroleums, especially Berthelot, Mendeléeff, Eli de Beaumont, De Lapparent, and a number of other writers mostly French and Russian.

But it evidently takes a long time to establish definitively even simple and palpable truths in science, as may be judged from some of the recent literature on the subject ([5]) in which the derivation of the natural hydrocarbons from organic matter is either again admitted without discussion or again sought to be proved. It appears, therefore, necessary that some of the facts in the case be once more presented, and I have adopted in this paper the comparative form between coals and petroleums, in the hope that it will bring out more forcibly and more clearly how entirely and absolutely different some of the natural carbon-compounds are to others in their nature, their mode of occurrence and their origin; and in the further hope that it will demonstrate that there are really two series of natural compounds of carbon, namely the Organic or the Coal Series, or Coals, and the Volcanic, or Petroleum Series or Petroleums.

NATURE.

Coal Series.—The coal series includes the natural carbon-compounds grading into one another from vegetation into peat, lignite, soft coal, semi-anthracite and anthracite. The exact chemical nature and proximate constitution of the members of this series are imperfectly known and are not yet fully made out, but they are nevertheless established to be complex oxidized carbon-compounds grading from definite carbo-hydrates into carbon-compounds richer and richer in carbon and poorer and poorer in oxygen as the natural carbonizing process of vegetation proceeded, the end product, anthracite, still retaining, however, some 2½ per cent. to 3 per cent. oxygen.

One hydrocarbon, namely marsh gas or methane, is known to form, during the natural decomposition of vegetation, into

5. The Data of Geochemistry, Bulletin No. 330, U.S. Geol. Survey, pp. 619–641. See also U.S. Geol. Surv. Bull. No. 250, 265, 282, 285, 300, 309, 317, 318, and others.

coals; this is the only hydrocarbon thus formed. Many other gaseous or liquid hydrocarbons may be produced by the destructive distillation of carbonaceous matter or of coals, but these have nothing to do with the carbon-compounds formed in nature by the normal geological processes, as the destructive distillation of the sedimentary strata and of its carbonizing vegetation is not a normal geological process and never took place. This is conclusively proved by all the undistilled lignite and coal beds of the sedimentary strata all over the world and by the want of coke beds in these strata.

It may be well to point out here also that coal beds, being more or less porous strata, may and no doubt have been impregnated, in places, with gaseous and liquid petroleums from extraneous sources and hence these particular beds of coal, in these places, will be found really to contain natural hydrocarbons; but these are the result of a secondary enrichment by impregnation of the original coal deposit. These cases are, however, the exception and do not in any way affect the problem, save as exceptions to prove the rule.

Petroleum Series.—The petroleum series includes all the natural hydrocarbons with the exception of the marsh gas above mentioned. These petroleums grade from natural gas into fluid crude oil or petroleum proper, into semi-fluid maltha and into viscous or solid bitumen or asphalt in their many varieties, of which such minerals as grahamite, gilsonite, elaterite, napalite, ozokerite, albertite, anthraxolite, are only a few. As the end products of the petroleum series there are good reasons, as we will see, to include both graphite and diamond, whose deposits prove that they also have had a similar inorganic origin.

A good definition of the nature of petroleum is the one of Mabery ([6]) as follows: "petroleum, from whatever source, is one and the same substance, capable of a simple definition:—a mixture in variable proportion of a few series of hydrocarbons, the product of any particular field differing from that of any other field only in the proportion of these series and the members of the series."

Mabery referred, I believe, in the above definition only to crude oil or petroleum proper, but it applies equally well to natural

6. Journ Am. Ch. Soc., 1906, XXVIII, p. 417.

gas, to maltha and to viscous or brittle solid asphalts, and, it may be said, therefore, that all the members of the great petroleum series, as here understood and defined, are mixtures of different hydrocarbons in greater or less variety.

MODE OF OCCURRENCE.

Coals.—With regard to the mode of occurrence of the members of the coal series it is only necessary for the purpose of this paper to note that they are always found in regular beds of the sedimentary strata spreading uniformly far and wide, often over hundreds and even thousands of square miles. The marsh gas of the decomposing vegetation has partly escaped into the atmosphere in the early part of the process or possibly even later, if the folding, fissuring and faulting of the coal measures have been strong, as for instance in the anthracite fields of Pennsylvania. What marsh gas did not thus escape, however, has not mysteriously transformed itself into the mixture of the many varieties of hydrocarbons constituting petroleums, but it is still found as marsh gas directly in the coal from which it originated and where it becomes to-day the dreaded fire damp of the coal miner, often mixed with considerable choke damp or carbonic acid and with considerable nitrogen. This gaseous mixture is a very different gas from the mixture of hydrocarbons constituting natural gas; it is never, like natural gas, associated with liquid petroleum and with large quantities of very strong salt and sulphur waters and can only be confused with it by superficial observers.

There is only one more point which I think pertinent to make here with regard to the mode of occurrence of the coals, and that is that no coal beds are found below the Carboniferous period. A small amount of coal or carbonaceous matter is, however, found in some of the Devonian shales, but this never passes into pure coal beds and fewer and fewer of these carbonaceous shales are found in the Silurian and Cambrian. The science of geology has always interpreted and explained this fact—that so little coal is found below the Carboniferous—on the understanding that before Carboniferous time the conditions for the existence of considerable growth of vegetable matter were unfavourable and it is a geological heresy to speak of or to believe in coal beds existing in formations

lower than the Carboniferous; geology teaches us that they cannot and do not exist there. How is it then that there are so many large deposits of petroleums below the Carboniferous? It could not be because there was so little vegetable or other organic matter entombed in these early strata, unless their origin is not in any way organic.

Petroleums.—If the mode of occurrence of coals is well understood, the mode of occurrence of petroleums certainly is not, and hence the great misunderstanding by so many concerning the origin of the latter. Instances are multiplying in which the natural hydrocarbons are found in emanations clearly volcanic and in igneous and volcanic rocks, that is, in places "where they have no business to be" ([7]) according to those who believe in and support the organic origin of petroleums. Nevertheless these petroleums are found often in such places and no well informed geologist can ignore this fact or refuse to take account of it. Some geologists have passed such, to them, unwelcome cases over with the remark that the petroleums in the igneous or volcanic rocks were no doubt due to the distillation of the bituminous shales cut through by the intrusions; but how can a hot rock distill or drive away a vapour into itself? Some new principles in physics would have to be discovered to permit of this explanation, which is simply a contradictory use of language and not a logical argument. It is also fallacious reasoning, a reasoning in a circle, to attribute the origin of oil to bituminous shales or to shales containing oil, that is to say to oil. In one of my previous papers ([8]) on this subject before this Institute I cited a good many instances of petroleums in volcanic emanations or in igneous or volcanic rocks, and for full particulars of these reference may be made to this publication, but I will recapitulate here what these instances prove beyond all doubt:

1st. The occurrence of graphite in igneous gneisses, granites, gabbros, pegmatite dykes and in a quartz-porphyry dyke.

2nd. The occurrences of hydrocarbons in the gaseous inclusions of the crystals of igneous rocks.

3rd. The occurrence of petroleums (liquid, semi-liquid and solid) in greenstone traps, in basalts, in trachytes, in dolorites and other volcanic rocks.

7. G. R. Mickle, Journ. Can. Min. Inst., Vol. VI, p. 123.
8. Journ. Can. Min. Inst., Vol. VI, 1903, pp. 73–128.

4th. The occurrence of diamond and gaseous hydrocarbons in volcanic necks and pipes.

5th. The occurrence of gaseous and liquid petroleums in the volcanic emanations of to-day.

6th. The occurrence of petroleum in freshly ejected scoriae from the volcano Vesuvius.

In confirmation of the above a few other direct proofs of the occurrence of petroleums in crystalline rocks, in volcanic or igneous rocks or in close connection with these, and in metalliferous veins, may be cited:—

1st. Oil in crystalline gneiss:—In Placerita Canyon, five miles east of Newhall, Los Angeles county, California, a very light oil, almost naphtha, of a gravity between 50° and 60° B., is produced from crystalline gneisses which overlay the San Gabriel granite ([9]). It was discovered in shafting for gold. There are seven wells there, producing from depths of between 400 and 1,100 feet, one of them yielding between five and six barrels per day of oil with 30 or 40 barrels of salt water, and another spouted high when the oil was first struck. The crystalline schist or gneiss in which the oil occurs is micaceous and granitic, conspicuously banded and greatly contorted.

2nd. Oil and bitumen in the quicksilver deposits of California:—The occurrence of petroleums in the Redington quicksilver mine, New Idria, Cal., and in the other quicksilver mines of that State, has been reported by Luther Wagoner ([10]), Prof. Egleston ([11]), Becker ([12]), Prof. Christy ([13]), and many others. It occurs abundantly as liquid oil, viscous tar, solid asphalt, and also in the gaseous state of natural gas intimately associated in the veins with the cinnabar and with metallic native mercury. Many other instances of petroleums found in quicksilver veins in Europe and in other metallic veins could be cited, in which the solfataric volcanic origin of not only the mercury or other metals, but also of the petroleum, is very apparent. The petroleum in such deposits cannot possibly have an origin different from that of the metals themselves.

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9. Bull. U.S. Geol. Surv. No. 309, pp. 100–101.
10. Eng. and Min. Journ., Vol. XXXIV, p. 334.
11. Trans. Am. Inst. Min. Eng. III, p. 273.
12. U.S. Geol. Surv. Monograph, XIII, pp. 371–373.
13. Trans. Am. Inst. Min. Eng., XIII, pp. 547–548.

3rd. Graphite and natural gas in the metalliferous vein of Silver Islet, and graphite in the veins at Cobalt and Ducktown, Tenn.:—The natural gas and graphite found in abundance at the Silver Islet mine has often been cited ([14]). Graphite was found there not only in the metalliferous vein intimately associated with rich native silver ores, but also in the norite or gabbro dyke accompanying the vein. At Cobalt graphite is also found in many of the complex cobalt-nickel arsenides and silver veins ([15]). Prof. J. F. Kemp in his paper on ([16]) "The Deposits of Copper Ores of Ducktown, Tenn.," says "graphite or some closely related carbon-mineral is met in occasional specimens of the ores of the Mary mine. It appears to specially favor the crushed masses and was probably of late introduction. It not only forms fine leaf-like aggregates but in thin section may be detected by the microscope as minute spheroids in the midst of other minerals, such as calcite and chalcopyrite. It must have been introduced as some gaseous or very mobile liquid hydrocarbon which has penetrated into minute cavities and filled larger cracks and has been subsequently changed to graphite."

4th. Solid petroleums in pegmatite dykes, and other veins, associated with uranium, radium and vanadium:—J. Obalski, in a very interesting paper ([17]) read before the Annual Meeting of this Institute, 1904, mentioned the fact that he found in a pegmatite dyke worked for mica a radio-active carbonaceous material burning quite easily and leaving ashes containing oxide of uranium, and also that he found in the same dyke some "cleveite," an ore of uranium strongly radio active and containing one tenth of a milligram of radium. Similar so-called "coals," which are, however, solid hydrocarbons or petroleums, are found in veins in Peru ([18]) and are mined for the vanadium they contain; these veins form lenses of "asphaltite" or solid petroleum from 0.5 inches to 22 feet wide and as much as 500 feet long, in a well-defined belt 15 miles long in the Yauli district, Peru; they are parallel and in close proximity to an obsidian intrusive dyke. In the Quespi

14. Eng. and Min. Journ., Vol. XXXIV, pp. 320, 323, 453. See also—Ore Deposits of the U.S. and Canada by J. F. Kemp, p. 283, and Eng. and Min. Journ., Vol. XXIII, pp. 54–55 and 70–71.
15. Prof. W. G. Miller, Bureau of Mines Report, Ontario, 1907, Pt. II.
16. Trans. Am. Inst. Min. Eng., XXXI, 261.
17. Journ. Can. Min. Inst., Vol. VII, pp. 245, 256.
18. Bull. Am. Inst. Min. Eng., No. 27, March, 1909, pp. 291–316.

district, Peru, there is another deposit of solid petroleum forming also a lens-shaped mass with a maximum width of 28 feet and length of 350 feet occupying one of the faults of a quartz-porphiry dyke. Similar occurrences of hydrocarbons containing vanadium and uranium have been cited by other writers (19).

5th. Graphite, diamond and hydrocarbons in meteorites:—It is well known that pure carbon in the form of graphite and diamond has often been found in meteorites (20), but it is not so well known that hydrocarbons have also been found in them as cited by N. V. Sokoloff (20). G. Tschermak also reports 0.85% of hydrocarbon in the meteorite which fell at Goalpara, India (20).

6th. Oil and natural gas in volcanic rocks in Europe, Africa and Mexico:—O. Silvestry (21) has found both liquid oil and a solid paraffin in basaltic lavas near the volcano Etna. Similar occurrences have often been cited from other parts of Europe, as for instance in Hungary (22), where liquid petroleum, asphalt and bitumen are found in rhyolite tuffs, in a rhyolitic quartz-trachyte and in andesite. On the Elansdraai farm (23), Hopetown district, Cape Colony, South Africa, two dolerite intrusive sheets were traversed in a well between the depths of 121 and 137 feet and of 364 and 401 feet and both were found to be rich in oil in their cracks and crevices. Many other dykes and sheets of intrusive rocks in Central British South Africa are also found richly impregnated with oil.

I have myself examined similar occurrences in dolerite dykes and in calcite veins running across Upper Cretaceous strata in the State of Chihuahua, Mexico.

7th. Natural gas in serpentine (24), Asiatic Turkey:—"On the southwestern coast of Asia Minor, north of Cape Chelidonia is the famous Chimaera or 'stone that burns,' of the ancient Greeks. Here gases are continually disengaged from fissures, and are known to have been burning for at least 2,800 years, as the phenomenon was described by Hesiod before the time of Homer. According to the Russian geologist, Tchiatcheff, the gas is emitted

19. See Bull. U.S. Geol. Surv., No. 330, pp. 611–616.
20. See Bull. U.S. Geol. Surv., No. 330, p. 632.
21. Gazz. Chim. ital. Vol. 7, p. 1, 1877; Vol. 12, p. 9, 1882.
22. Trans. of the Inst. of Min. Eng., Vol. XXXV, pt. 6, p. 721.
23. Trans. of the Inst. of Min. Eng., Vol. XXXV, pt. 4, pp. 545–558.
24. "Mineral Industry," New York, 1903, Vol. XI, p. 514, 515.

from fissures in an altered igneous rock (serpentine) which is intrusive in limestone."

8th. The occurrence of oil around volcanic necks, Mexico:— As described by Ezequiel Ordonez ([25]), in the State of Tamaulipas, Mexico, in the Gulf-Coast lands, the oil deposits are found around vertical borings, chimneys or pipes drilled upward through undisturbed and almost horizontal shales by volcanic action during the Pliocene and perhaps Post-Pliocene times and forming small isolated cones ranging from a few feet to four or five hundred feet in height. These cones of volcanic origin spread over the coastal peneplain and consist either of solid basaltic lava or of basaltic tufa. At the base of these cones, or in their neighborhood, are to be found the greater number and more important seepages of oil. The Mexican Petroleum Company, at Ebano, near Tampico, have obtained their more productive wells at the base of the tufacious cones, such as the Cerro de la Pez, where from but very few wells around this hill they have secured a daily output of 6,000 barrels. In the more highly productive wells of this company the heavy oil, abundantly charged with gas, carries a sandy material consisting of small sharp pieces of shale, fine lapilli, and volcanic sand. The conditions above described as to the occurrence of oil prevail in an extensive zone of the Gulf-Coast lands and extend further south in Mexico to the northern half of the State of Vera-Cruz. Any number of cones, peaks and pyramids of volcanic origin are here also distributed over the coastal plain piercing through very slightly folded or undulated strata of shales, interbedded with limestones and sandstones in thin layers, the whole probably of Upper-Cretaceous age. The oil seepages are always found here also around the volcanic hills but more frequently near the isolated volcanic peaks than in places where such peaks are closely grouped and surmounted on large bases which are composed of lava streams preventing the oil from seeping out to the surface. Mr. Ezequiel Ordonez further says ([26]), "In the coastal plain lying between Tampico, Tuxpan and Papantla will be found the greater number of volcanic hills and the more important and densely distributed oil-seepages of Mexico. I shall name a few of them: near the Laguna de Tam-

25. Mining and Scientific Press., Aug. 24, 1907, pp. 247–248.
26. The Mining and Scientific Press, Aug. 24th, 1907, p. 248.

iahua there exists a large pool of asphaltic oil, close to the twin volcanic hills known as Los Hermanos; not far from the Sierra de Tantima is another big, dry asphaltic lagoon; on the hacienda de Tiacolula we found two oil seepages, one on either side of the basaltic hill called Temaxcales. The large volcanic mountain near the hacienda de Tamatoco gives birth to several exudations of oil; on the eastern side and not very far from its base is found one of the larger seepages named La Chapopotera de Juan Felipe, having an extent of one-half mile. The Chapopotera de Cerro Viejo, those of the hacienda del Chapopote and others nearer Tuxpan are also extensive and important." It is along the Laguna de Tamiahua mentioned by Mr. Ordonez as affording a large seepage of asphaltum oil close to the twin volcanic hills known as Los Hermanos, that S. Pearson & Son's wonderful and uncontrollable oil gusher ([27]) has since been drilled in a property known as the San Diego de la Mar, at a point on the lagoon known as Dos Bocas. The first well drilled on this property by the firm of Pearson & Son came in at 2,005 feet with an estimated production of 5,000 barrels of oil daily. The second well came in on July 4th, 1908, at a depth of 1,824 feet and the oil flow was so enormous that it lifted the 1,283 feet of 8 inch casing in the hole and also the 43 feet of $11\frac{5}{8}$ casing, and broke out in every direction on the outside of the casings catching fire from the boiler and burning, it is said, for a time at the rate of 100,000 barrels of oil daily, and for 57 days before it could be put out by pumping sand and gravel into the crater formed around the well. Three weeks after the fire was put out the diameter of the crater was 400 feet and soundings taken 30 feet from the sides showed a depth in places of 200 feet. Approximately two acres of earth dropped into the crater at one time from the sides. This crater later on became so big that the well was finally abandoned and it is now a veritable geyser of oil, mud and water, throwing out, it was estimated on November 1st last, 14,000,000 barrels of an emulsion of oil, mud and water.

Other instances could be given here of petroleum deposits directly connected with vulcanism, but the one just cited is enough to prove that oil fields are not "commonly remote from great indi-

27. Eng. and Min. Journ., Jan. 2nd, 1909, pp. 7, 8 and 9.

cations of volcanic activity" as it has been contended ([28]), and that on the contrary enormous quantities of oil are obtained in the porous sediments or tufacious sands around volcanic necks. When the petroleums are found, however, in the igneous, volcanic or crystalline rocks themselves it is impossible to find more than small quantities, as the necessary porosity to store these products in large enough amounts to be economically valuable is, of course, wanting on account of the imperviousness of the crystalline texture of these rocks. These small quantities of hydrocarbons are nevertheless found in many regions all over the earth in whatever small cavities, cracks and seams is co-existent with the crystalline texture of the igneous, volcanic and crystalline rocks and even in microscopic inclusions inside of their crystals.

On the contrary, in the sedimentary strata of all ages some of the sediments, principally sandstones, conglomerates, limestones and sandy shales are occasionally quite porous rocks, and therefore may and do form catch basins, tanks or reservoirs for gaseous or liquid petroleums forcing their way under strong pressure through the fractures, fissures, seams and joints of the strata. These reservoirs when thus filled constitute the important petroleum deposits, the commercial oil—and natural gas-fields. They are found indiscriminately in hundreds and hundreds of horizons in the strata of all ages, from the oldest Paleozoic to the alluvial gravels and sands of the Quaternary. The natural gas or gaseous petroleum in these reservoirs is always found to have a heavy pressure, sometimes as high as 1,500 pounds to the square inch and in this connection the most important fact to be noted is that this pressure increases in each particular field with the depth of the porous reservoir or "sand" containing the petroleums, indicating that its source is from below. It has been proven ([29]) beyond a doubt that this pressure is not a descending artesian or hydrostatic water pressure, the main proof being the uniformly decreasing pressure of the gas as it is being taken out; nor is it a pressure exerted by the weight of the superincumbent strata since the gas is in the pores of firm coherent rocks not under crush. The origin of this pressure requires no explanation and becomes self-evident when the true volcanic origin of the petroleums is understood.

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28. The Data of Geochemistry, U.S. Geol. Surv. Bulletin, No. 330, p. 633
29. Journ. Can. Min. Inst., Vol. VI, pp. 96–99, and Vol. III, pp. 68–89.

Far from forming, like the coals, uniform beds, spreading out uninterruptedly in every direction over wide regions, the petroleum reservoirs on the contrary are always found to form comparatively small, local, accidental and irregular pockets, pools or fields. In these pools or fields themselves extreme irregularity is often the characteristic of the reservoirs; patches and strips of barren and productive territory being intermixed in most intricate manners, leading often to productive wells being surrounded by dry holes, and vice versa. In many of these fields the oil and gas are obtained in a number of different sands or reservoirs, some of which are hundreds and thousands of feet lower than the upper one and again in that respect in some of the fields there is great irregularity as to what depth the producing reservoir will be found; in neighbouring wells the oil or gas may be tapped at entirely different depths. To any keen observer the above features at once demonstrate absolutely that the petroleums in all of their reservoirs are wanderers, not in their original home, and that all their deposits are deposits of secondary impregnation. This adventitious character of the petroleums in all their deposits is a self-evident proposition when the ever present strong pressure of their natural gas is remembered. Fluids so elusive, ready to gush out with such force the moment the drill pierces their reservoirs and evidently ever impelled upward through disturbed, faulted and fractured strata by the strong pressure of their gas, can never be in their original home and the evidence that they are not is most abundant. But there is another most important feature of the oil and gas fields, and that is they are generally very much elongated in one direction, and the different fields or pools of the same district are always arranged in lines along folded and fissured zones or belts parallel to the tectonic structure or to the orogenic uplifts of the region. The maps of the Appalachian oil- and gas-fields and of the Northwestern Ohio oil- and gas-fields published by the respective geological surveys of these States illustrate this last feature most eloquently and demonstrate that these fields form two parallel oil and gas belts to the Appalachian range of mountains, each belt being several hundred miles long. Many other illustrations of this may be found in the maps of the oil- and gas-districts of California, Galicia, Rumania, Russia and other regions. The oil- and gas-fields in these last mentioned

countries are always found ranged in belts at the foot and on each side, respectively, of the Coast Range, of the Carpathian mountains and of the Caucasus mountains. It is most marked in Galicia and Rumania where the Carpathian mountains form, as is well known, a semi-circle and the oil- and gas-fields also form the same semi-circle on both sides of the mountains and along their foot hills or ranges. This reminds one of the metallogenetic provinces referred to and indicated by some geologists in regard to the incoming of particular metals into the strata at various periods of the earth's history in connection with certain volcanic manifestations and intrusions of that particular period, and along the great orogenic uplifts of that period. De Launay, Lindgren, Spurr and others have, in several of their writings, pointed out clearly some of these metallogenetic provinces. The alignment of the petroleum-fields in every region in parallel belts to the orogenic uplifts or to the tectonic fissuring of that region shows conclusively that there are also in nature "petroliferous provinces" or petroleum-bearing belts, no doubt due to causes similar to those which have given us the metallogenetic provinces, namely:—tectonic disturbances accompanied by volcanic emanations. As De Launay remarks, in his "Science of Geology" ([30]), "the dislocations of the earth are more and more observed to have taken place, not alone in mountainous regions but even in regions of plains;" he also remarks ([31]) that "all the regions of the earth, probably without exception, have been subjected to dynamic movements to which are connected igneous manifestations of internal origin." These remarks will explain how petroleum-fields even at long distances from mountainous ranges and in flat plains, such as the Northwestern Ohio, Ontario, Indiana, Illinois, Texas and Louisiana fields, etc., can nevertheless be connected with the tectonic structural dislocations of this continent and to the volcanic emanations which have accompanied these structural dislocations during the different geological ages. For further proofs of the connection of oil- and gas-fields with the disturbances of their region, even in the States which I mentioned last where it is not at all apparent on the surface, I refer you to

30. La Science Géologique, L. De Launay, Paris, 1905, p. 229.
31. La Science Géologique, L. De Launay, Paris, 1905, p. 351.

the following papers:—one by G. D. Harris ([32]) on the "Geological Occurrence of Rock Salt (associated with petroleum) in Louisiana and Eastern-Texas,"another by H. Foster Bain ([33]), State Geologist of Illinois, on the "Geology of Illinois Petroleum Fields," to the records of the late Edward Orton ([34]) on the Northwestern-Ohio fields, and to one of my previous papers ([35]) before this Institute.

In the California oil-fields a most obvious connection is to be seen in most of the fields, between the occurrences of oil and the very strong and profound disturbances of the strata occasioned by the orogenic uplifts of the hills and mountains of the Coast-Range. Contrary to many other oil-fields, the oil is here often found in highly disturbed and intensely crushed strata and in many cases along well defined and prominent structural faults. I refer you to Eldridge and Arnold's most interesting bulletin ([36]) on the Santa Clara Valley, Puente Hills and Los Angeles districts of Southern California, for many good proofs and examples of this. Briefly the evidence in this bulletin shows conclusively that the oil-fields follow, in narrow but long belts, the much disturbed and faulted zones at the foot of the higher mountain ranges of the Coast-Range, and that the oil is found to be stored in the porous reservoir-rocks or in the seams and joints of any and all the strata affected by these disturbances in a vertical geological scale of some 25,000 feet including at the bottom crystalline schists and gneisses resting on granite, then a great thickness of Tertiary resting unconformably on these crystalline schists, then an upper unconformable series, partly Tertiary and partly Quaternary, called the Fernando, and finally, overlying all, unconformable beds of the Quaternary. To go into more details the oil is found in the Santa Clara Valley in ascending order in the following formations:—

In the crystalline schist and gneiss penetrated by the wells to a depth of 1,100 feet; above this there is a great unconformity but the oil is still found in the following strata in ascending order:—

32. Economic Geology, Vol. IV, No. 1, Jan. and Feb., 1909, pp. 12–34.
33. Economic Geology, Vol. III, No. 6, Aug. and Sept., 1908, pp. 487.
34. Geology of Ohio, Vol. VI, p. 46, et seq.
35. Journ. Can. Min. Inst., Vol. VI, pp. 102–108.
36. U.S. Geol. Surv., Bulletin No. 309.

Lower Eocene—Topatopa quartzites, sandstones and hard shales ..... about 5,500 ft. thick

Upper Eocene—Sespe red sandstones and conglomerates ..... about 3,500 ft. thick

Oligocene—Vaqueros shales, limestones and sandstones ..... about 3,000 ft. thick

Miocene, Modalo sandstones and shales (probably equivalent to the Monteray formation) . . about 3,500 ft. thick

Here there is another distinct unconformity but above it we still find oil in the—

Miocene, Pliocene and Pleistocene—Fernando conglomerates, sandstones and arenaceous clays ..... about 9,000 ft. thick

Here again is another distinct unconformity but above it we again find the oil in the Pleistocene gravels, sandstones, clays and conglomerates, of variable thicknesses.

The total thickness of the formations more or less impregnated with the oil is .....about 25,600 feet.

Although we have here three geological unconformities, meaning long lapses of time and erosion between the deposition of the different formations, yet the oil is in all of them, through a thickness of over 25,000 feet of strata, from and including the crystalline rocks to the most recent gravels, but only along great fault-lines and zones of disturbances. There are three conclusions to be drawn from this which are plain:—1st, the movements of the oil were vertical, not lateral; 2nd, some of these movements were of recent date, namely Post-Quaternary; 3rd, it cannot reasonably be supposed, as some geologists have, that this oil originated in any one of these formations (such as the Monterey which is often cited by Arnold as the source of the oil) as this would entirely fail to explain the oil in the formations below the Monterey and also the oil in unconformable formations above the Monterey. Oil formed from decomposition of organic remains in the Monterey, as supposed by Arnold, would either have remained in that formation if the Monterey shales were impervious enough to prevent its escape into the atmosphere, or, if they were not, would have exhausted out into the atmosphere long before the Fernando and Quaternary strata were deposited unconformably over it. There

is only one possible explanation, namely:—solfataric volcanic emanations of hydrocarbons coming up from below the crystalline gneisses along the fault-lines and in the zones of disturbances at repeated periods of dynamic movements of the Coast-Range, and some of these movements must have been very recent to explain the oil in the gravels of the Quaternary. Even in the Monterey shales, as in all the so-called bituminous shales, it is plain that the petroleum is a secondary product of impregnation subsequent to the forming of the shales, as evidenced by the fact that these shales are bituminous only along the zones of disturbances and in local and irregular pools; in these, it is not in any way spread over uniformly in one or more beds but it is distributed in the shape of branching streaks, veins, patches and in the joints and cracks; in fact the portions impregnated with bitumen often look like a regular breccia, indicating plainly the injected nature of the bitumen ([37]).

In one of my former papers ([38]) on this subject before this Institute I have emphasized by other examples this well established geological fact with regard to the occurrence of petroleums illustrated grandly by the California example just cited above, namely: —that the petroleum deposits belong to no special horizon of the geological scale, and that they are found in any and all of them, including the crystalline rocks, and as we have seen, also in volcanic emanations, in volcanic and igneous rocks, in metalliferous veins and in meteorites. When to this consideration we add the further one that these petroleum deposits are found in great abundance in certain districts in the porous reservoir-rocks of thousands of feet of the geological scale but only when these are aligned in narrow long belts along certain structural lines, while neighboring districts outside of these lines but with the same geological sequence of formations are absolutely barren, we see that we must necessarily consider petroleums as secondary products of impregnation and replacement coming up along these structural channels from a source below the last formation in which it is found, namely the crystalline rocks. It must also necessarily be inferred that the latest incoming or emanations of these secondary petroleum products through all these strata are younger than the youngest impregnated formation.

37. Bulletin Geol. Surv., No. 317, pp. 39–41.
38. Journ. Can. Min. Inst., Vol. VI, pp. 109–113.

The solid petroleums are also found in zones of great fracturing and of profound disturbance, in parallel vertical veins following the general direction of the orogenic uplifts of their particular district and cutting all the strata and in every way similar to mineral veins. This is well proven in California, Utah, Indian Territory, Galicia and other places, instances of which will be found in one of my other papers (39) on this subject. Arnold (40) and Ells (41) have both shown instances from California and from the Barbadoes Islands, respectively, in which the solid petroleum was replaced in depth in the same vein by liquid petroleum.

In some of the more recently formed oil- and gas-deposits, as in Texas and Louisiana, where the oil and associated salt waters are often hot yet, the petroleums occur in vertical chimneys of salt, gypsum, sulphur, calcite, dolomite and silica replacing and uplifting Quaternary, Tertiary and Cretaceous clays and sands, and forming peculiar qua-qua-versal domes called salines, mounds or salt islands. The local uplifts in some of the salines of Louisiana and Texas is extraordinary, as much as one to two thousand feet in an elliptical area but a mile or so across, and these salines, as Capt. Lucas pointed out long ago, are ranged along straight lines (42). Mr. G. D. Harris, in an article just published (43), gives us an interesting map of the structural lines of dislocation of this region, and shows that they belong to two systems more or less at right angle one to the other, and parallel to the great Balcones fault for the northeast system and to the Red River and Alabama Landing fault for the northwest system; he also shows that the salines are all located along these lines of weakness and he claims at the intersection of two of these lines where a still weaker point was determined "admitting the upward passage of fluids or gas under pressure from below;"—but Mr. Harris is still under a similar impression as Mr. Robert T. Hill was (44), namely:—that these gaseous and liquid substances are carried to these salines by artesian waters entering the pervious layers of the Mesozoic or Paleozoic far up country and going down to greater and greater depths as

39. Journ. Can. Min. Inst., Vol. VI, pp. 104–108.
40. Bulletin No. 309 and 317, U.S. Geol. Surv.
41. The Geology and Mineral Resources of Trinidad and Barbadoes Islands.
42. Trans. Am. Inst. Min. Eng., Vol. XXIX, p. 463.
43. Economic Geology, Vol. IV, No. 1, Jan. and Feb., 1909, p. 12.
44. Trans. Am. Inst. Min. Eng., XXXIII, 363.

the latitude of the gulf border is approached to ascend under hydrostatic pressure at the above mentioned points of weakness. As I have pointed out twice before ([45]), several years ago, the pressure to which the fluids under the salines are subjected is not hydrostatic and it is also impossible for meteoric waters to gather and carry down from sediments the diversified products of these salines especially insoluble liquid hydrocarbons and such gases as natural gas and hydrogen sulphide. Permit me to recall here the explanation of the nature of these salines which I gave before this Institute six years ago ([46]):—"But, on this continent, in the newly discovered oil-fields of Texas and Louisiana, we have many no less direct evidences of vulcanism, though they do not appear to have been understood in their true light. These are the salt islands and the mounds of the Coast-Prairie such as the famous 'Spindletop' near Beaumont, which are clearly nothing else but 'suffionis' or 'salses' hardly extinct yet, grouped along fractured lines and marking in that region the dying out of vulcanicity, that is to say the dying, distant echo of that tremendous volcanic energy which, a little further south, in Mexico, Central America and in the islands and along the south coast of the Caribbean Sea, is to this day so powerfully active." When these occurrences of petroleum in the Texas-Louisiana salines are considered in the light of what is now being found a little further south along the gulf-coast plain in the new oil-fields of Mexico, where, as noticed above, the oil is found around volcanic necks, it can be seen that the view which I took six years ago that these salines were regular solfataric volcanic vents was the right one;—in the Mexican oil-fields the volcanic action has been a little more intense and instead of only the hot gases, vapors and waters piercing up more or less through the horizontal strata to form the salines, as in Texas and Louisiana, we see the volcanic lava cones themselves piercing up boldly through the plains. There is no doubt that these lava cores in Mexico surrounded with petroleum and other solfataric emanations are one and the same volcanic phenomenon as the vertical chimneys of salts, hot waters and hot petroleums of the Texas-Louisiana salines.

45. Journ. Can. Min. Inst., Vol. VI, p. 93 and Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 292, 293.

46. Journ. Can. Min. Inst., Vol. VI, p. 89.

ORIGIN.

The opposite chemical nature of the members of the two series of natural carbon-compounds, namely, oxidized complex carbon-compounds for the coals and a mixture of reducing hydrocarbons for the petroleums, gives us the first hint of the surface or external origin of the coals and of the internal origin of the petroleums. Beneath the earth's surface, as is well known, there is a deficit of oxygen, and hence we find none in the natural hydrocarbons from the interior, except in the solid varieties which are the oxygenated and sulphureted residues of the other petroleums in places where they came near enough to the surface. The coals on the contrary obtained their oxygen from the atmosphere at first in their original state of vegetation, and have retained part of it during the carbonizing process to which they have been subjected.

Coal Series.—The origin of the members of the coal series from the natural decomposition of vegetable matter, either in place or drifted, is abundantly proven, and is now generally acknowledged and admitted among geologists.

Petroleum Series.—It is, however, very different in the case of the petroleums, the origin of which is still admitted by many, as a matter of fact requiring no demonstration, to be due to some unseen and unexplained decomposition of organic matter. Other geologists have discussed the subject at length and have tried to prove the organic origin of the petroleums, but not one has ever been able to point out to a single case where a petroleum production process coeval with the kingdoms of life could be witnessed in nature to-day. Some other geologists are discouraged and proclaim the origin of petroleums as a profound mystery not yet solved by science.

As I have long contended, I, for one, cannot understand how it is that the solfataric volcanic origin of the petroleums should be considered as any more doubtful and less proven than is the organic origin of the coals. It seems to me that the geological facts proving the one are just as clearly established scientifically to-day as are the facts proving the other. They are simple facts, the A. B. C., so to say, of geology, and yet strange to say they are every day ignored and set aside.

There can be only two kinds of organic matter in nature to which the derivation of petroleums might be attributed, namely:—*First*—The soft tissues of animals. *Second*—Vegetation.

1st.—But the soft tissues of animals always decompose, decay completely and disappear entirely before their entombment in the sedimentary strata can possibly take place. It leaves us, therefore, only the vegetation to deal with in the consideration of this problem. That the soft tissues of dead animals entirely disappear before the entombment of their hard part, even in the comparatively rare cases where the entombment of the latter takes place, is one of the best known and best proven facts in geology;—water, carbon dioxide and ammoniacal salts, are the chief products of the decomposition ([47]), no petroleum is formed. If it had been otherwise we would not find, as we do, even in recent Quaternary deposits, many beds composed entirely of ostreas, corals and shells of all kinds such for instance as the "coquina" beds of Florida, absolutely devoid of some carbon-compound to represent the supposed entombed soft tissues of the animals; while, in the fossil-shells and other hard parts of the animal life which we have collected in great abundance in our paleontological museums, from strata of every geological age, we would surely often see at least a modicum of some carbon-compound; but we may examine millions of these fossils and see nothing of the kind, even when these fossils were collected in impervious shales from which the decomposed products of the soft tissues of the animals, if they had been entombed and had decomposed there, could not possibly have escaped. In very rare cases we do find portions of strata with shells or other fossils filled up with liquid petroleum, but in these cases we also find the seams, joints and other open or porous parts of these strata impregnated with the same fluid, showing plainly that it is a secondary product of infiltration and replacement. Many other substances have thus filtered through the strata and petrified or mineralized the fossils, such as calcite, silica, pyrites and a great many other, including such metals as copper and mercury. In all such cases there can be no implication of a community of origin between the infiltrated products and the organisms. Yet many geologists often quote some of these rare occurrences of petroleum in hard

47. Bulletin U. S. Geol. Surv., No. 330, p. 116.

parts of organisms and use them as evidence bearing in favor of the derivation of it from these organisms, whether fish, mollusk or other organisms. For instance, in a recent memoir on the natural hydrocarbons by Frank Wigglesworth Clarke ([48]), I find the following:—"Dieulafait observed that the copper shales of Mansfield are strongly impregnated with bitumen and also rich in fossil fish. The petroleum of Galicia is always associated with menilitic schists in which fish remains are peculiarly abundant . . . . . G. A. Bertels, on the other hand attributes the Caucasian petroleum to the decomposition of mollusks. In the Kuban district, the oil, accompanied by salt water, exudes directly from beds of molluscan remains, which occur in enormous quantities." I wish to point out in answer, that in the great majority of cases even traces of fossils of any kind are impossible to find in the prolific oil- and gas-sands of the United States and of the other parts of the world at large, and therefore that one is arguing the rule from the exception when he relies on such rare cases as cited above for his proofs of the organic origin of the petroleums; also that in the copper shales of Mansfield, there is as much reason to attribute an organic origin to the copper as to the petroleum; also that in Galicia the petroleum is found in much greater quantities, than it is in the menilitic schists, in sands without any fossil fish, and that it is found also in very large quantities, as ozokerite, in parallels and branching veins cutting lower strata than the menilitic schists; and finally, that the salt water which exudes with the oil from the mollusks in the Kuban district must also have its origin in the decomposition of the mollusks, according to the reasoning used.

There are a few instances cited in geology of partially decomposed and preserved remains of animal bodies having been found, but these are most exceptional cases, such as a few remains preserved in the antiseptic waters of peat bogs or a few frozen remains of Elephas. These exceptions of course only confirm the rule, which is, namely:—when there is anything left of animal life in the strata it is the shells or bones, or their moulds or casts, but there is no trace of the flesh or soft tissues to be found, as none of it was entombed.

48. Bulletin U.S. Geol. Surv., No. 330, pp. 635.

All that has been written, therefore, about petroleums being derived by distillation or otherwise from the soft remains of animal organisms, whether macroscopic or microscopic, entombed in the strata cannot possibly have taken place in the natural geological processes, since no such remains were ever entombed in the strata. C. Engler, C. M. Warren, F. H. Storer, S. P. Sadtler and others ([49]) have experimented and produced hydrocarbons by destructive distillation of organic animal matter, and these syntheses are often quoted by some geologists as very strong proofs in explaining the origin of the natural hydrocarbons in a similar way, but as it has been shown above it is impossible to suppose that there could be any similar normal process in nature, since not only the soft parts of the animal organisms were never entombed in the strata but the sediments in the oil-fields were also never subjected to the high temperature required for the destructive distillation in such experiments, namely between 300° and 400°.

2nd.—Now as to the vegetation:—Is it not also absolutely and most abundantly proven that vegetation decomposes naturally into the coal series of carbon-compounds, and are not all the members of this coal series found all there in the sedimentary strata? Nothing more can be asked from vegetation. Are not all the stages, the beginning, the middle and the end of its gradual carbonizing process into peat, lignite, soft coal, semi-anthracite and anthracite right there before us ever since the very beginning of vegetation in Silurian or Cambrian times? Are we to disbelieve what we see to have taken place by the billions of tons during all ages since these most ancient periods, namely, that vegetation carbonized into the coals, and are we to imagine instead that some other unobserved, unseen and mysterious transformation of vegetation into something else, namely petroleums, took place? This would be to lay aside an abundance of proven facts in order to adopt a mere supposition. The normal process of decomposition of vegetation into coals in nature is in active operation in the world today as it has always been, and it is the only one that we can see. It is also the only one of which we have any record in the long history of the geological ages.

49. Bulletin U.S. Geol. Surv., No. 330, pp. 629, 630.

As to the other argument that by destructive distillation the petroleums can be obtained from the coals, that would be all very well if nature had distilled the sedimentary strata and the coals or other vegetation in it, but as a matter of absolute fact it has not; therefore this line of argument also falls to the ground at once and can be dismissed. If the sedimentary strata had been distilled and petroleum thus produced there would be no coals anywhere on the globe; we would have nothing but coke beds.

The belief in the organic origin of the petroleum leads also to chaos in the understanding of other geological facts and physical laws brought out clearly in the study of many petroleum occurrences or deposits, and no wonder that some geologists who are inclined to believe in this organic origin exclaim therefore that the genesis of petroleum is a profound mystery not yet solved by science. For instance:—

1st.—It cannot possibly explain the large petroleum fields below the Carboniferous.

2nd.—Neither can it explain the petroleums in the volcanic emanations of today.

3rd.—Nor in the volcanic or igneous rocks in all parts of the world.

4th.—Nor in crystalline rocks; in California and New Brunswick, for instance.

5th.—Nor in meteorites.

6th.—Nor in metalliferous veins.

7th.—It is also at a loss to explain why the petroleum fields in every district are found grouped along certain lines and why the petroleums are found there in many horizons, while outside of the lines in just the same strata and over much larger areas all the horizons are barren.

8th.—It cannot explain either how the petroleums can possibly travel out of their supposed organic-remain source in some impervious clay or shale to accumulate in a few porous receptacles far distant laterally and some times hundred and thousands of feet above, or even below as some assert, and this all through most impervious rocks and without any impelling force behind, or any cracks, joints or fissures to follow since the decomposed

products of the organisms must naturally be supposed to come from the whole mass of the strata through which the organisms were and there could not be fissures, cracks and joints to all parts of the strata.

9th.—It cannot possibly explain why the petroleums, although found today in their reservoir-rocks under strong pressures, cannot by means of that pressure, return and disperse back to their original sources; they should be able to return the way they came, nothing is to prevent them and there is plenty of pressure for the return voyage if one admits the first voyage from the organic source.

10th.—It cannot possibly explain either how the petroleums from the organic remains in the Monterey formation for instance, in California, got out into the unconformable series above, such as the Fernando formation and the Quaternary, and why these petroleums did not all get out into the air during the long lapses of time marked by the unconformities, and how they were able to get into the lower Eocene and the still lower crystalline rocks, thus working their way against the pressure of their own natural gas which always increases with the depth.

11th.—It cannot possibly explain again, if the petroleums can travel so freely through the strata as to be able to accumulate under an anticline from organic remains deposited far and wide laterally (at least a mile or two or much more in order to allow for the quantities obtained in many fields), why they did not escape out into the free air only a few hundred or a few thousand feet away at most; the shales above the sands are not any more impervious than the shales below the sands, which on that theory are supposed to be the source of the petroleums, and if they can travel freely through the shales which are the most impervious rocks of the sedimentary series, I repeat, what is to prevent them from getting out into the atmosphere?

12th.—It cannot account for the continual absence of petroleums in the hard parts of organisms preserved in the sedimentary strata.

13th.—It cannot explain the evident non-connection of petroleum deposits with coal-beds.

14th.—It cannot account for the continual association of petroleums with strong salt and sulphur waters.

The origin of the petroleums, therefore, is not organic; that it is volcanic is absolutely proven by:—

1st.—The fact that volcanic emanations of hydrocarbons are the only natural geological process of petroleum production of today, abundantly verified and witnessed in actual operation in volcanic eruptions and phenomena all over the world.

2nd.—By the presence of petroleums in volcanic rocks, igneous rocks, metalliferous veins and meteorites.

3rd.—By the rock pressure of the natural gas in the petroleum deposits. This pressure always increases with depth in each field; it has been well proven that it is not an artesian water pressure from above, and it cannot be explained in any other way than as a remnant or spark of the volcanic energy forcing the petroleums through the crystalline rocks and all the sedimentary strata from below.

4th.—By the products associated with the petroleums in their reservoirs, principally salt, sulphur, hydrogen sulphide, gypsum, calcite, dolomite and silica, which are also the products associated with hydrocarbons in the volcanic emanations of today. This association is the unmistakable solfataric volcanic seal which I pointed out before ([50]).

5th.—By the hot oils, gases and waters in some of the more recently formed petroleum-fields.

6th.—By the fact that the petroleum deposits are located along the faulted and fissured zones of the crust of the earth, parallel to the great tectonic, orogenic and volcanic dislocations and in "petroliferous provinces" analogous to the metallogenetic provinces of DeLaunay, Lindgren, Spurr and other writers. These petroleum deposits could not be inseparably and intimately connected with the tectonic structure of each particular region unless their source was as deep seated as the forces which have caused these profound dislocations of the crust. We have gradually come to this conclusion in geology in regard to ore deposits similarly connected with tectonic disturbances; and hydrocarbon gases and vapors must be added to this class of solfataric metalliferous emanations and receive their proper place in geology as solfataric "petroliferous" emanations. These "petroliferous"

50. Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 290–294.

emanations have played a most important part in the deposition of ore bodies ([51]).

7th.—By the fact that petroleums are never indigenous to the strata in which they are found, and are clearly secondary products impregnating porous rocks of all ages. In all fields there is always a lower horizon in which the petroleum is found, until finally the crystalline rocks are reached, and they are even found in these. This adventitious nature of the petroleum deposits is further illustrated by the deposits of solid petroleums which cut through all rocks in veins exactly similar to mineral veins.

8th.—By the fact that petroleums are found in such abundance in certain small localities, while neighboring localities are found entirely barren; this forces one to the conclusion that they must originate from the volcanic tank below which is the only one adequate to furnish these enormous quantities to narrow long belts or to small isolated spots, such for instance as the one hundred acres of the Spindletop Mound, near Beaumont, Texas, which has already produced about 38 million barrels of oil; such as the one billion of barrels produced from a small area in the famous oil-field of the volcanic peninsula of Apcheron, near Bakou, Russia; and such as the millions of barrels produced in many other fields from very narrow long belts while areas many scores of times larger next to the producing strips are barren; this cannot be held to be an accumulation in the producing fields from vast surrounding areas of sediments, as if this was supposed one could not explain why the petroleums did not escape to the surface instead of travelling so far laterally.

9th.—By the fact that the sedimentary strata of the oil-fields are so highly impervious that the volcanic fracturing and fissuring and the volcanic force of the natural gas alone can explain how so many small porous receptacles at different horizons between these impervious strata, have been filled with petroleums, salt and sulphur waters, and how these small detached petroleum-reservoirs are found to-day under a gas pressure which increases with depth in each district but is nevertheless a stored energy which will dissipate gradually in the utilization of the oil-field, the volcanic energy which brought it there at one time being now dead and inactive.

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51. See Walter P. Jenney, The Chemistry of Ore-Deposition, Trans. Am. Inst. Min. Eng., Vol. XXXIII, p. 487.

Before concluding permit me to insist on the fact that the recognition of the solfataric volcanic origin of the petroleums not only removes every difficulty in the way of a full comprehension of all the chemical and geological facts established to-day with regard to the nature and mode of occurrence of these products, but it fully harmonizes also with the physical laws governing the circulation of gases and liquids through great thicknesses of very impervious strata before being able to reach to and accumulate in a few small separated receptacles in the midst of these. The volcanic origin of the petroleums forms, therefore, a complete chain of evidence, with none of the links weak or missing. The very reverse is the case, as I have shown above, when one attempts to explain the origin of the petroleums by means of organic sources;—in doing so, well known chemical and geological facts are set aside and ignored and physical laws are distorted and abused. The geologists who still hold these views should seriously reflect on this, and I am confident that if they do they will soon abandon and relegate to the past the old unsupported notion of the derivation of petroleums from organisms and that they will come to the conclusion that this idea is now unworthy of the progress made by the geological science of today.

When one considers that there were produced in the United States alone last year 184 million barrels of oil and fifty-three million dollars worth of natural gas, he can fully appreciate the great economical importance which petroleums have attained. It is essential, therefore, even leaving aside the purely scientific aspect of the question, that the origin of these products should be understood in order to afford a basis or guide for the intelligent exploration of the many new fields yet undiscovered and which are to supply the world with even vaster quantities of petroleums in the future. The correct understanding of the volcanic origin of the petroleums furnishes us at once, as a matter of fact, with the solution of this problem of how and where to look for new fields; we must follow, as I have pointed out before ([52]), the structural or tectonic lines of disturbances and fissuring or the fractured belts along which the solfataric hydrocarbon emanations came up from the interior. The outward manifestation of these tectonic disturbances may be a fissured anticline, as

52. Trans. Am. Inst. Min. Eng., Vol. XXXV, p. 297.

it often is, but the fissuring may also have occurred at any other part of the structural folding of the strata whether in the syncline, at a monocline, along a slope or terrace or at other parts of any form of structure. The so-called anticlinal theory, as heretofore explained and understood, namely, as a favorable place of accumulation under an arch of the supposed products of decomposition or distillation of organisms, is absolutely untenable and without any meaning. Such products cannot and do not travel through impervious strata as well demonstrated by the fire damp and choke damp of the coal mines which are always found today right in the beds of coal from which they originated. If hydrocarbon gases and fluids could travel through the shales below the producing sands which in this organic theory are supposed to be their source, these hydrocarbon fluids would also travel just as freely through the shales and other strata above the sands and therefore would have escaped out into the atmosphere long ago instead of stopping under the anticlines. There is absolutely no difference between the degree of perviousness of the strata above or below the "sands," in fact very often a shale which is above a producing sand is also below another producing sand. All these strata are highly impervious, including even the "sands" which are porous only in occasional comparatively small spots. It has been impossible, therefore, for gases and fluids to travel through the strata except when they were fissured by profound dynamic disturbances which permitted the tremendous volcanic pressure from below to exert itself, and even then the enormously pent up gases and vapors from the interior reached to or near the surface with great difficulty as exemplified by the great differences in pressures of the natural gas in different sands at various levels in a given field, by the fact that although natural gas pressures of 500 to 600 lbs. to the square inch are often obtained quite near the surface, at depths of only 800 to 1,000 feet, yet the gas did not escape, and, by the further fact that oil- and gas-fields are such small detached pools never extending but short distances away from the dynamic disturbances which formed their original channels. It is only as a part of this broader conception of the occurrence of the petroleum-fields along the profound structural disturbances that the so-called anticlinal theory has any merit. This conception alone explains why some fissured anticlines are

"petroliferous," or petroleum-bearing, in several of their sands, at different horizons, while the great majority of anticlines are absolutely barren of hydrocarbons at all their horizons because they are not fissured folds in "petroliferous provinces."

DISCUSSION.

DR. ALFRED C. LANE (communicated to the secretary).—Mr. Coste's interesting paper very ably summarizes the arguments against the *solely* organic origin of carbon compounds. The argument is convincing, and one can add little to it. One might add references to the work of Brun at Geneva, and the recent work of R. T. Chamberlin, for the Carnegie Institution, in which one will find an account of a test on a Michigan mill core. It had been reported that illuminating gas was found in Michigan copper mines as at Silver Islet, and so I had a piece of core (No. 86) sent to Mr. Chamberlin, upon which he made tests, finding illuminating gas as in many other rocks.

But on the other hand it is very difficult to prove a negative that oil and gas may not have been derived from organic matter. Even in the Silver Islet mine, in view of the Huronian black slates of various ages, such an origin cannot be said to be impossible.

Practically Mr. Coste goes to the other extreme and would rule an organic origin for petroleum out of court entirely.

Is it true, however, that no petroleum production process caused by the activity of bacteria within the kingdoms of life can be witnessed in nature to-day? I had supposed that sundry barrels of spoiled pickled fish showed something of the sort. My grandfather was a fish dealer.

Is it true that "the soft tissues of animals *always* decompose, decay completely, and disappear entirely before their entombment in the sedimentary strata can possibly take place?" The italics are mine.

Is the marsh gas of mud lumps of deltas entirely from vegetation?

Again in the decomposition of vegetable matter, say algal matter, say *Chara foetida*, how can Mr. Coste limit the production to the peat-graphite series? Let him smell some once. In what shape is the organic matter in one of our so-called "marl" beds, such as is used for cement? This is a bog lime or limestone dough.

In a lake deep enough to be stagnant the bottom water is foul, free from oxygen, and complete decomposition does *not* go on, or goes on with exceeding slowness. My colleague, Dr. Birge, of the Wisconsin Survey, is accumulating a mass of facts bearing in this direction.

The processes and stages of decomposition that we may now see are vastly more complex than Mr. Coste grants.

Then turning to the geological column, Mr. Coste has not shown that there are not petroleum compounds in the Utica shale, the Marcellus shale, the Portage or Genesee shale, the Berea shale, the Scotch oil shales. I do not think he will say that these are derived from beneath, from the thousands of square miles over which these formations have their black colour and contain a number of per cent. of "volatile carbon." Of course, this is usually obtained by distillation; but Mr. Coste gives no means by which one may distinguish such organic hydrocarbon from his inorganic.

If he will give some such explanation, we can then test the drillings of black shale from numerous points, and the "stink kalk" or fetid limestones containing bituminous matter, and then see how widely the supposed organic and supposed inorganic petroleums are distributed.

Rarely is the Berea struck without some sign of oil or gas, or the Trenton without some "organic matter," and this universal distribution is a difficulty in accepting the seductive hypothesis so ably urged by Mr. Coste.

THE PRESENT POSITION OF THE COAL-DUST PROBLEM.

By James and John Ashworth, Manchester, England.

(Western Branch Meeting, Victoria, Sept., 1908).

The subject of Coal-Dust is still one of the most important questions which can be discussed by any meeting of Mining Engineers, and it therefore deserves very careful and detailed treatment, but for the purpose of the present meeting and for the useful advancement of information on this particular subject, the authors have condensed their matter so as to provide ample scope for the discussion of possibly every phase of coal-dust theories.

At the outset it may be of advantage to state what they mean by "Coal-Dust," as connected with colliery explosions—generally speaking, therefore, when they refer to coal-dust they will have in mind the very fine dust which is ordinarily present in coal mines and continuously produced from the coal in course of transit from the working face to the pit shaft by friction and that such dust is more dangerous than the older dust which has settled on the sides, roof and timbering of the mine.

The authors submit the opinion that this dust is the most dangerous factor in all collieries, particularly where fire-damp is produced, and think that the many disasters which have occurred in Canada and the United States of America, are sufficient in themselves to take as examples, to convince every careful observer and student of Coal-Dust Phenomena, that terrible disasters such as Monongah and Darr were mainly due to the part played by floating coal-dust, and that the incomplete combustion of this dust coupled with the heat due to the pressure developed, acting on the older dust, creates the huge volume of carbon-monoxide gas which is the actual life destroying element of every colliery explosion. To make their views on the universal production of carbon-monoxide gas more clear, they have to express the opinion that the enormous and sudden pressure created underground by explosions of mixtures

of fire-damp and air, or of fire-damp and coal-dust, or of air and coal-dust, is sufficient by itself to produce huge volumes of carbon monoxide gas without the addition of actual flame, and in support of this contention quote the latest estimates of these pressures made by Mr. J. T. Beard, of the Universal Correspondence Schools, Scranton, Pa., and of Prof. H. M. Payne of the West Virginian University, U.S.A. The former in his recently issued text book, entitled Mine Gases and Explosions, estimates the possible pressure at 196 lbs. per square inch, and the latter at from 50 to 146 lbs. per square inch.* And the difference in these estimates arises from the volume of air available, and particularly so in Prof. Payne's estimate which was based on what he considered did actually occur at Monongah.

The sudden and instantaneous effect of these great pressures on the miners, is to produce loss of consciousness or in some cases death by concussion of the brain, and thus men are found in the precise positions they occupied at the moment of the explosion, or when less severe pressure is produced they are overtaken by the afterdamp before they recover consciousness and are thus poisoned and killed in a few seconds.

Authorities are divided as to whether a small quantity of dust or a dense cloud is the more dangerous, but the authors' experience and observation leads them to the conclusion that in the majority of instances it is the dust floating in the air which is dangerous, and therefore if more than this comparatively small quantity is present, there is then an insufficient volume of air to complete the combustion, and the flame is smothered out. Experience and observation also lead them to conclude that dust is more dangerous in a damp atmosphere than in a dry one and that there are numerous cases on record where a mine has been described as dry and dusty, whereas the air was either saturated with moisture or so nearly saturated that not more than one grain of water vapour per cubic foot would have completed the saturation.

Writers and experts on coal-dust phenomena are generally in accord in treating coal-dust as a very small solid, but the authors of this paper think that it ought not to be treated as a solid but as a concretion of gases, because Prof. Bedson, D.Sc., of the Armstrong College, Newcastle on Tyne, has proved by experiments

*Mines and Minerals February, 1908.

extending over many years, that every particle of coal-dust freshly produced from the coal face, contains both fire-damp and other gases of the paraffin series under pressure, and that these are continuously giving off until the supply is exhausted, and that they are then replaced by oxygen from the atmosphere and not by air, as the atoms of nitrogen are too large to pass through the pores, and are therefore filtered out. Consequently it will be readily understood that freshly produced coal-dust being surrounded by the gases escaping from the store occluded in its own small body, floats as it were in its own balloon of gas, and is therefore immune from any dampness in the air current or in fact from any form of water. In many instances the expert evidence given to ascertain the initiatory cause of an explosion is evenly divided between coal-dust only or fire-damp only, being the agency by which the original cause, generally a flame from a shot, was extended some distance into or throughout a colliery; and the authors submit that no enquiry of this class can in any case be complete, until the dust has been examined by what they may term the "Bedson process," and that such an investigation would be still more complete if the structure of the dust were examined under the microscope, as was done by Mr. W. E. Garforth after the explosion at Altofts, in England, several years ago.* Taking these two sets of experiments (both due to private initiative and not to the application of public funds) into plain matter of fact consideration the authors conceive that it has been proved by Mr. Garforth without the possibility of dissent that coal-dust is not a solid but is possessed of pores, and by Prof. Bedson that gases exist in these pores under considerable pressure, and therefore that every particle of freshly produced coal-dust ought to be considered as a "gas" and not as a solid. Accepting it as a gas bag surrounded by air, it is in its most favourable condition and position to inflame and explode, and thus to initiate or extend the effect of any flame which is of sufficient intensity to ignite it.

This course of argument and practical demonstration naturally leads up to another of their conclusions on the use of explosive,

*See the Report of the Royal Commission on Explosions from Coal Dust.

viz.: that it is not possible to use any known explosive with absolute safety in a gaseous mine.

There is, however, another danger which is probably never taken into account, viz., that due to detonation. Every high or so-called flameless explosive requires the application of a detonator, and if the detonator is not sufficiently strong, ignition and not detonation is the result; but assuming that the detonation is complete and that it is an over-weighed shot, we have then to contend with results which are in some senses more dangerous than a blown out powder shot, because we have created a huge detonating vibration which is unaffected by any amount of watering, and which may be communicated to the most distant corners of a mine without demonstrating any effects en route. Supposing therefore that either large or small accumulations of fire-damp mixed with air exist in any part of a mine, these may be simultaneously exploded by this detonating effect. The Wattstown explosion in South Wales was probably an instance of this effect.

The question which naturally seems to follow this line of thought is "what percentage of fire-damp is permissible in a mine or place where explosives are used," and this is not so easily answered, because experiments have already demonstrated that less than one per cent. may be dangerous. If then one per cent. of fire-damp will make a mine dangerous, it would appear rather absurd to blast excepting in such cases where it is absolutely necessary, and then only under the most stringent precautions, but the absurdity of the position is increased when we find that the usual tests for fire-damp are made with safety lamps which are incapable of discovering less than two per cent., and on this showing the mine is certified as clear from gas and safe for shots to be fired. The only possible safeguard which the authors have to suggest to add to the safety of gaseous mines when explosives are used, is to limit the weight of the explosive in each shot, that is to say, a large number of small shots might be safe where the same weight of explosive in one shot might cause a disaster,—for this valuable discovery, "the charge limit," the writers believe we are mainly indebted to French engineers. The conclusion of the writers is that not more than one per cent. of fire-damp is permissible, and that the weight of explosive per shot hole should be limited.

As to whether it is possible to render a coal mine safe against the initiation or extension of an explosion by any application of water, the writers are of opinion that it is *positively impossible* to restrain the extension of an explosion by any known means of applying water, and further that any form of water to dampen the air assists in the extension of an explosion, because as proved by Prof. H. B. Dixon the maximum explosive effect of mixtures of gas and air are only obtained when the atmosphere contains five per cent. of water vapour, and as this percentage can only be attained by the use of steam it is therefore an impossible application and the writers say positively that there is no known means of applying water so as to control the extension of an explosion.

The difficulty of applying water does not however end here, because the weight of water which will saturate an air current may vary from say 4 to 13 grains per cubic foot, and therefore either 4 or 13 grains ought to be equally effective in controlling the extension of an explosion, but this proposition is absurd when we have already proved that five per cent. of the weight of the air and gas mixture is required to give the maximum explosive effect, that is to say not less than 25 grains per cubic foot of the mixture.

Possibly resulting from the escape of the occluded gases from coal dust, it has been found to be extremely difficult to dampen fresh coal dust, and a practical demonstration of this fact was given to the jurymen at the Monongah inquest by putting about a pound of fine dust into a basin of water, and after stirring it up, and pouring off the water, blowing into the dust when it immediately flew about the court room like soot.

The possibility of rendering a deep dry and dusty mine proof against the extension of an explosion by water saturation has however another barrier against its adoption, and investigation has demonstrated in the most positive manner possible, that if miners are to work in such mines with any degree of comfort or efficiency the air must be kept as dry as possible, so that the perspiration from their bodies can pass into the air and afford a sense of coolness, but if it does not, then the body temperature rises until what is now described as "heat apoplexy" results,

with loss of muscular power, and the men die. In many deep mines the heat ranges from 75 to 90 degrees Fahr., and therefore if the air were saturated with water (9.14 to 14.8 grains), the miners could not possibly work. About 8 grains of water vapour per cubic foot of air should be the maximum dampness permissible in the air of a deep mine.

Another phase of the coal-dust problem still remains to be considered, viz.: the explosion of dust in mines where fire-damp has never been discovered, such as Camerton and Timsbury, in the Somersetshire coalfield, in England, and so far no experiments have been made to ascertain if any or what gases are occluded in such coal-dust, and as these explosions have originated in old roads it is possible that the dust had become altered by exposure to the air current and having absorbed oxygen had become more susceptible to the influence of flame. Only by submitting such dust to courses of experimental research similar to those already referred to can its ignition or explosion when exposed to a flame of great intensity be satisfactorily explained.

The possible speed of a coal dust explosion has frequently been debated, but without reliable data, on which to base an opinion, until the Monongah disaster, when the difference of time between the explosion reaching the surface outside of No. 8 and No. 6 mines respectively was observed to be five seconds, and one of the writers has calculated that this would give a speed of 3,000 feet per second. This fact is particularly interesting because it quite upsets those theories which require a considerable time to produce a series of explosions which are not instantaneous, and do not take into account the effect of cooling or condensation.

The writers trust that these few notes, on a subject which has such a wide range of interest, may be sufficient to provoke very considerable discussion and result in the gathering together of much very valuable information and also produce suggestions for some better and more effective means to exorcise the demon of coal-dust than the present day ineffective systems of watering.

Note.—Messrs. J. B. and W. N. Atkinson, E. Bainbridge, W. E. Garforth and W. Galloway made an estimate of the velocity of the explosion at Altofts based on the movement of materials and this was placed at 90 to 100 miles. Coal Dust Report Q 3821.

If per minute this would be 7920–8799 feet per second or more than the speed at Monongah, but if per hour this would only be 132–147 feet per second.

Gases Enclosed in Coal and Certain Coal Dusts.*

To show that coal after removal from the mine not only gives off its "enclosed gases" but takes up gases from the air and oxygen preferentially to nitrogen, analysis was made with the following results:—

	Freshly hewn Coal.	Coal after exposure to the air.
Carbon Monoxide	1.65	1.18
Oxygen	8.79	23.80
Marsh Gas. Fire-damp	44.60	3.58
Nitrogen	44.76	71.44
	100.00	100.00

The sample of dust from the Fernie mine (remarkable for its fineness) the gases differ from those of the dusty seam in character of the combustible constituents, which are undoubtedly mixtures of higher homologues of the marsh gas series. In fact, the composition of these gases is not dissimilar to that of the gases obtained by Bedson from the Ryhope Coal dust and coal.

Fernie coal dust at ordinary temperature gave 12.8 c.c. of gas from 100 grammes of coal.

The coal at atmospheric temperature gave (d) 22.2 c.c. and at 100 Cent. (e) 23.1 c.c., and Carbon dioxide 35.4, Oxygen 1.0, CnH_2n, 0.4, Carbon Monoxide 7.9, $CnH_2n \times 2 = 52.7$, and N. 2.6. Paraffines.

The results of the explosion of the combustible constituents of these gases gave the following values for "n" in the formula

*By F. G. Troubridge, Society of Chemical Industry.

$C_nH_{2n}\times 2$, in "a—"n=1; in "b," n=4.4; in "c"—n=2.1; in "d"$_2$n=1.8, and in "e"—2.5.

When ordinary analysis of coal is being made the sample is usually dried at a temperature of 100° Cent. and therefore the gases given off as above are dissipated before the ordinary analysis commences.

Mr. W. E. Garforth's microscopic examinations of coal dust showed the presence of spores of cryptograms also the megaspores and microspores of some cryptogamous plants (Selaginella).

OXYGEN BREATHING APPARATUS IN COAL MINES WITH A PARAGRAPH ON THE RESCUE STATION OF THE DOMINION COAL CO., GLACE BAY, CAPE BRETON.

By F. W. Gray, Sydney, C.B.

(Annual Meeting, Montreal, March, 1909).

The history of oxygen breathing apparatus, and its use in coal mines is a curious commentary on the conservatism of British methods, and incidentally on the enterprise of the Germans. The development of these devices to the present standard of efficiency has taken place almost entirely on the Continent of Europe, and more particularly in Germany and Austria.

It is, therefore, a little surprising to find that the prototype of the accepted form of modern breathing apparatus was the invention of an Englishman, Mr. Henry Fleuss of Newcastle-on-Tyne, who in 1880 designed an arrangement, the principle of which he explained as follows:—

"The wearer breathes his own breath over and over again, the carbonic acid being absorbed from it at each expiration, and the requisite amount of oxygen being restored, the re-vivified air is fit to be again inhaled in the form of pure air."

This description would very well serve for the standard apparatus of to-day, for Mr. Fleuss's device embodied all the essential features of the modern oxygen-regenerative type of breathing apparatus.

Mr. Fleuss's invention seems somehow to have been entirely overlooked in England for over twenty years; but, in the meantime, mining engineers and chemists in Germany, France, Austria and Italy were devoting their energies to the perfection of similar devices.

For years, however, several members of the British Institution of Mining Engineers, notably Mr. W. E. Garforth of Nor-

manton Collieries, West Yorkshire, and Messrs. G. B. Walker and M. H. Habershon of Tankersley, South Yorkshire, had persistently advocated the provision of rescue stations on the lines of German practice.

Mr. Garforth, at his own expense, erected an experimental gallery for the training of men, and he devised an apparatus now known as the "Weg". His efforts marked the first stage of systematised colliery rescue work in England, as his present labours do the systematic investigation of coal-dust explosions, and the Normanton Rescue Station was the first in the Empire.

Then followed the Tankersley Station, which was erected in 1904 by a group of colliery owners. The station was first equipped with the old Giersberg helmet, but is now furnished with Draeger apparatus.

Outside of the two pioneer stations just named, however, it is only within the last three years that rescue stations on a general scale have been erected outside of Germany and Austria. In British mines the real advent of oxygen breathing apparatus dates from the epochal disaster of Courrières, which occurred almost exactly three years ago, and gave opportunity for the spectacular despatch of the German corps from the Hibernia Colliery.

The Courrières disaster attracted attention, not only by reason of the very large death-roll, but because it was thought at the time that if breathing apparatus had been immediately available some lives might have been saved. As events turned out the Hibernia corps rendered useful service in the recovery of the mine, and were found of great value in dealing with the decomposed corpses of the victims of the disaster.

Breathing apparatus are now being used for the same melancholy duty at the Radbod Mine in Westphalia, where it will be remembered 300 men recently lost their lives.

Breathing apparatus may be divided into two main types, namely, what for want of better names we may call the stationary and portable types.

The first-named generally consists of a protecting hood or mask attached to a hose-pipe, by means of which air is pumped to the wearer in much the same way as air is conveyed to a diver. Such an apparatus is inexpensive and easily "rigged-up," and is often useful for such work as the building of dams against under-

ground fires. The "Anaconda" hood, described in a recent issue of the *Engineering & Mining Journal*, is a simple apparatus of this type, which has been used with successful results in copper mines. A more elaborate device is the "Kœnig" helmet, largely used by German fire brigades.

The chief drawback to the stationary type is of course the limited range of action.

The second main type includes the apparatus which are self-contained and carried about the person of the wearer. They may be said to have practically superseded the first-named type.

The portable apparatus can be roughly divided into three kinds, as under:—

1. Developments of the oxygen-regenerative device of Fleuss in which the breath of the wearer is passed over an alkaline that absorbs the carbon-dioxide, and is returned to the wearer, supplemented by pure oxygen under pressure.
2. Liquid air, represented by the "Aerolith" apparatus.
3. Apparatus in which a special chemical compound will release oxygen when exposed to the breath, represented by the "Pneumatogen."

The development of this type of apparatus from the Fleuss to that of to-day has been mostly in the direction of the complete absorption of the carbon-dioxide of the expired air, on the success of which the apparatus is chiefly to be judged. In the former types the elimination of CO_2 from the breath exhalations was so imperfect that the wearer usually developed a splitting headache and nausea. In the modern apparatus such as the Fleuss, Draeger, Westfalia, &c., the alkaline absorbent does its work so effectually that the percentage of CO_2 in the air for respiration is lower than that of ordinary atmospheric air.

The last named type has afforded the lightest apparatus yet designed, namely the "Pneumatogen," which weighs 8 lbs. only. The "Pneumatogen" uses sticks of potassium-sodium-peroxide, which when exposed to the breath exhalations absorb the carbon and the water and release oxygen in large quantities. This apparatus requires a "primer" of oxygen to start it, and takes a little time to get warmed up and in operation. The chief objection to the arrangement has been the difficulty of obtaining a chemical

of sufficient purity, as the slightest particle of foreign matter will cause ignition of the compound.

There are many who think, however, that the idea represented by the "Pneumatogen" is the one along which future developments in breathing apparatus may be expected. In other words the future of breathing apparatus is thought to be in the hands of the chemist, because in the oxygen-regenerative devices later referred to it would seem that the art of the instrument maker and the mechanic has been carried to its perfection.

The "Pneumatogen" is the only breathing device yet invented which could be used to any large extent for "self-rescue." Someday—possibly in the near future—further developments in this type of apparatus may be anticipated, as the inventors of the "Pneumatogen" are still working at the problem, and are understood not to have abandoned the idea of perfecting their invention.

The "Aerolith" is the only apparatus using liquid air. It possesses certain advantages, namely that it permits of a plentiful supply of cold air, which can be arranged to last longer than most of the oxygen apparatus, and at the same time it is fairly light. The objections are that liquid air cannot be stored without a certain leakage, and where no liquid air manufactory is near, it is necessary to put down a plant to make it. In isolated positions this practically debars the use of the "Aerolith."

The principal apparatus included in the term "oxygen-regenerative" are the Draeger, the Fleuss-Siebe-Gorman, the Weg, the Westfalia, and some apparatus made in France and in the United States. They all possess essentially the same features, namely a reservoir of compressed oxygen, and an exposed surface of absorbent alkali over which the breath exhalations pass, connected together by a system of tubes and bags, and fitted either with a helmet covering the head, or some form of mask or mouthpiece.

A description of one apparatus will serve—with a few modifications in each case—as a description of the general type, and as an account of the Dominion Coal Company's rescue station is to follow, we will describe the Draeger apparatus.

The distinctive feature of the Draeger apparatus is the helmet, which consists of a brass mask covering the face and the crown of the head, but leaving the ears free. It is fitted with a large

mica pane for vision, and is lined with a pneumatic tubing, which can be inflated and deflated in the same manner as a bicycle tyre, enabling the helmet to be fitted closely to the curves of the facial outline, and entirely excluding the outer atmosphere. The helmet communicates through tubes with the breathing bags on the chest and the oxygen cylinders in the backpiece. There are two breathing bags, one for the expired breath, and the other for the revivified air awaiting use. The bags serve to equalize the pressure and they also show if the apparatus is working properly. The breath exhalations pass along the circulating tube and diffuse through a series of flat dishes of net, covered with coarsely granulated alkali, so arranged as to give the greatest possible amount of absorbent surface. From the alkali cartridge the purified air passes through a cooler and joins the main stream of oxygen, which issues from the reducing valve of the cylinder at a pressure of 125 atmospheres. The whole apparatus fully charged weighs 36 lbs., and will supply the wearer with 3,000 cubic inches of air per minute for at least two hours. The wearer is entirely independent of the outside air, and it has been proved that most exhausting work can be accomplished in smoke and heat and gases.

With the exception of two or three cases in Prussia, the use of breathing apparatus has not availed as yet to save life after mine explosions. The Draeger apparatus is said to have 35 lives to its credit, men who were rescued immediately after explosions, who but for the immediate use of the apparatus by rescue parties would have succumbed to the "after-damp."

But in the great majority of coal mine explosions that have occurred in recent years, such as that of Courrières, France; Kharkov, Russia; Radbod, Westphalia; Abram, England, and the awful succession of explosions that marked the year 1908 in the United States, the destruction has been wholesale and complete, and more than once not a man has survived to tell the tale of how it happened. From the meagre cabled reports it would appear also that the recent West Stanley explosion in England was one of considerable violence.

Where rescue apparatus have been at hand the original catastrophe has usually rendered its use of no avail, and in one or two cases where lives might have been saved the apparatus arrived too late, as at Hamstead and at Courrières.

All this, however, is no argument against the provision of breathing apparatus, but rather one for its more extended use.

The erection of rescue stations is the merest farce if other precautions are neglected. If coal-dust is allowed to accumulate in the roadways of a mine, if unsupervised and unskilful blasting is allowed, if naked fire of any kind continues to be tolerated in coal-mines, then the provision of breathing apparatus for rescue work is but added foolishness. But wherever mining is conducted as it should be, the modern breathing apparatus offers possibilities that render it a necessary part of the equipment of a modern coal-mine.

The advantages of breathing apparatus in fighting underground fires are unquestioned, and there can be but little doubt that the greatest usefulness of these devices will be developed as aids to fire protection.

Invariably, almost, the greatest obstacle in extinguishing a mine fire in its initial stages is the difficulty of reaching the seat of the fire through the smoke and fumes. To the fire-fighter equipped with a helmet apparatus and an electric lamp, the smoke and fumes present no difficulties, and he can penetrate to the fire and fight it with hose or chemical extinguisher at short range.

The list of underground fires successfully combated with the aid of oxygen breathing apparatus is steadily growing.

In *Glückauf* of January 30th, 1909, Bergassessor Grahn communicates an account of a great fire in the Testasecca sulphur mine near Palermo, which was successfully dammed off by men using Westfalia type of helmet apparatus. In previous cases of fire in sulphur mines it has always been necessary to abandon the mine temporarily and flood the workings. By the use of breathing apparatus in building a dam it was found possible to choke out the fire in seven days, and thus avoid the cost and loss of output which flooding necessitates.

In Canada, the Draeger apparatus of the Dominion Coal Company was successfully used in the fighting of a fire two and a quarter miles underground in the workings of Sydney No. 1 Mine. A detailed account of this incident will be found in a paper read before the Midland Institute at Doncaster (England) recently.

At the Wharncliffe Silkstone Colliery, South Yorkshire, a fire broke out in an electrical haulage-engine house situated about

1¼ miles underground, and was successfully extinguished by men from the Tankersley Station wearing Draeger apparatus. In this case the fumes of the burning electrical connections and oil in the controller boxes were dense and choking, and the fire could not have been approached without the protection of helmets. This mine has six coal seams all working and connected with each other in an intricate manner by cross-measure drifts and shafts, and it would have been well-nigh impossible to flood the workings.

During 1908, there have been four or five similar incidents in coal mines in the United States. In the case of the Schoenberger mine of the Pittsburgh-Westmorland Company breathing apparatus were of especial service under most difficult conditions.

In Germany the use of breathing apparatus in connection with colliery fire-brigades is so usual that it has ceased to evoke any particular comment.

There are two clearly defined uses for breathing apparatus in coal mines, namely, their use for the rescue of human life after explosions, and their use in fighting underground fires.

The first matter is the concern of the State, the second devolves upon the coal operator, and these uses should not be confused.

The corporation that for the protection of its own mines equips them with breathing apparatus, and the employees of that corporation who voluntarily train themselves to effectively use the apparatus, are expected to respond to any call of danger in their own mines, but when disaster overtakes a neighbour conditions may well arise that would justify trained men to refuse to risk their lives in a strange mine, even to attempt the rescue of their fellows.

Having in the past suffered very largely from mine fires, the Dominion Coal Company in 1907 decided to erect and equip a rescue station. After due consideration of the various breathing apparatus on the market the Draeger apparatus was selected. At the present time the station is equipped with 20 complete sets of apparatus, and 15 other sets are distributed around the outlying collieries. Every apparatus is maintained in a condition of readiness for immediate use, and fully charged. There are also 35 duplicate twin-cylinders for the back-piece of the apparatus, and these are kept fully charged. In addition to this a reserve

of 1,000 feet of oxygen is maintained in large store cylinders holding 100 cubic feet each. The stock of potash cartridges is over 1,800. The Draeger apparatus has been not inaptly likened to a gun, the ammunition of which is the oxygen and potash refills. The cylinders and the cartridges can be unshipped and replaced with others in a few minutes, and so long as the ammunition is to hand work can go on indefinitely so far as the apparatus is concerned. It is therefore of importance to have a sufficient stock of spares and refills.

An electric hand-lamp is kept for each apparatus, and these are of course kept in immediate readiness for use, being charged by the Instructor in the station itself.

Instruction in the wearing of the apparatus is given daily in the smoke-chamber, which is a wooden building without windows or ventilation. For practice purposes it is filled with a dense smoke, into which the men go wearing the apparatus and carrying electric hand-lamps. The training in breathing consists of lifting a heavy weight attached to a rope which passes over a pulley, known as the "exerciser." The men train for from 45 to 60 minutes at one time.

At the present time the Coal Company have over 100 men, in addition to officials, who are expert in the wearing of the apparatus. They are divided into corps of five men, each colliery having from one to four corps, according to the size of the mine. These men are also taking instruction in first aid to the injured.

The equipment of the station comprises an oxygen rescusitating apparatus,of the "Brat" type. This device differs from the ordinary arrangement for administering oxygen to an unconscious man in that it not only forces pure oxygen into the lungs, but it will also exhaust the poisonous gases from the lungs. By simply turning a handle the lungs of the patient are deflated and then inflated, exactly simulating natural breathing. It has recently proved of great value at the Grossherzog von Sachsen Colliery, Dietlas, Germany, where a number of men were overcome by a sudden outburst of carbon-dioxide in the mine. They were all brought back to consciousness by the use of the "Brat" reviver, although several of them had been given up by the doctors as dead.

The station has also a stretcher, made to run along wheels on the mine floor, and capable of being pulled by one man. The

stretcher is fitted with an arrangement for supplying oxygen to an unconscious or injured man strapped on. By means of this stretcher and the "Brat" apparatus referred to it would be possible for a party equipped with helmets to penetrate into unbreathable gases, rescusitate unconscious men, and pull them out to fresh air on the stretcher.

It may be confidently anticipated that should the necessity arise the Dominion Coal Company's men will give a good account of themselves. They have trained conscientiously, and the little experience at Sydney Mines has given them absolute confidence in the apparatus and its possibilities.

DISCUSSION.

Dr. Porter:—I have nothing to add to what Mr. Murray has said in regard to the great usefulness of this apparatus, but one point I think might be brought out, namely, under ordinary conditions rescue stations can only be established by concerted action of several companies or by the Government. The Dominion Coal Company is by far the greatest of our coal companies, and operates a large number of mines all in one district. Thus it has felt justified for its own protection to establish a rescue station and train its men. The cost of such a station with an attendant who must be a skilled man, is such that a smaller company could not afford to do it, and as a result the Dominion Rescue Station is the only one at present in the country. Even in the United States there are but one or two stations—one I believe supported in part at least by the United States Government.

It seems to me that the great function of these stations is not so much to save life after an accident, although that was its primary purpose, as to combat mine fires and lessen their destructiveness both of property and life. The matter is of such importance that those of us who are interested in the development of the country might well bring our influence to bear on either the Provincial or Central Government, with a view to arranging if possible for government support or assistance looking to the establishment of rescue stations and the training of men in the different coal mining centres.

A station of this sort would have a radius of 50 to 100 miles. There has already been one case, as Mr. Murray said, in which a fire would probably have been very disastrous if it had not been for the station. The local people at a mine belonging to another company fought a fire for some time without success and when it became clear that they could not contend with it, the men from Glace Bay were brought over, and the fire was immediately put out. Such cases have become quite frequent abroad and we all remember the occurrence in France of the terrible Courrieres disaster a few years ago, where men came all the way from Germany to help in the rescue work. Now, if we had one of these stations in the Crow's Nest Pass and one or two in the Pictou and Springhill district, supported either by contributions from the various mines, as is done in England, or by the Government, as is done in Germany, it seems to me we would make a very great step in advance. I should like to suggest at least to the council that this matter be taken under consideration with a view of memorializing either the Dominion or Provincial Government or both in the hope that something might be done in this country.

MR. MURRAY:—I would add that the United States Government has already erected a station in Pittsburg, a well equipped training station, where the men from the various collieries will be sufficiently trained in the use of the apparatus to give them confidence in their underground work, and they are contemplating, I believe, the erection of four or five other stations. They have already recognized definitely the immediate need of some such step, and their example no doubt would be of use in presenting the subject to the proper authorities in Canada.

THE PRESIDENT:—There are not very many coal mining men in attendance at this meeting, but I think Dr. Porter might bring this subject to the attention of the council at the proper time that recommendations may be made.

DR. PORTER:—I should like to call the attention of the meeting to some work which is now being carried on in connection with the study of the fuel resources of the Dominion. Several years ago the United States Government started a very extensive and elaborate series of tests of the coals of the United States. Shortly afterwards Mr. Low, then recently appointed Director of the Canadian Geological Survey, undertook a similar series of tests for

Canada, and owing to the somewhat exceptional facilities which we possess at McGill University, and to the fact that I had been carrying out some few experiments in the same line on my own account, he did me the honour to ask me to take charge of the work. I now wish merely to outline what is going on as I hope that we shall be able to publish formal reports in the course of a few months.

We have taken samples of about one hundred coal seams in different parts of the Dominion, from the extreme Eastern part of Nova Scotia to the Yukon. Wherever the circumstances have justified it, these have been quite large, and in all we have taken about fifty samples of from eight to ten tons each. The samples were taken by an officer of the Geological Survey—the Mines Department as it is now—who has had special experience in that direction, and every care was taken to ensure their being perfectly representative of the commercial output of the mine. These large samples were sent to Montreal, where they were crushed to $2\frac{1}{2}$ inch, thoroughly mixed so as to get a uniform product, and then sampled and sacked for subsequent treatment in the University. A portion of two or three tons of this carefully mixed coal was then sent to our boiler testing plant and was tested on approximately fifty horse power scale under a Babcock-Wilcox boiler, and a complete series of determinations of the actual steam production, the heating value of the coal, and its quality as regards clinker ash and so on were made; together with a complete series of chemical determinations both of the ash and of the flue gases. Similarly a lot of a couple of tons was submitted to gas producer and gas engine tests. We found in the beginning that there was no commercial producer on the market, whose manufacturers would guarantee it to deal with the very varied coals of this country, and so we had to begin this branch of the work by an elaborate series of experiments, first of all with the various producers on the market, all of which failed to satisfy the conditions, and ultimately in the design and construction of special down-draft producers. In a general way Canadian coals yield more tarry matter than the German coals upon which the main part of all past gas engine work has been done. So that an essential part of our investigation was the development of a producer which could work on our average coals. Ultimately Prof. Durley succeeded in designing a producer which

is now doing most satisfactory work. We have succeeded with this one producer in making good effective commercial power gas from the lignites of the plains, from the anthracite of Banff, and from the highly tarry coals of Nova Scotia. This to my mind is an achievement on the part of Prof. Durley and his staff which, in itself, is more than sufficient return for the cost of the whole investigation.

This work, owing to the delay in getting a satisfactory producer, is still in progress, and any member of the Institute who is interested will be welcome to visit the producer plant.

In addition to the boiler and gas engine tests, we carried out washing tests on each of these large samples, to determine whether it is practicable to wash the coals. This washing has not been merely an experimental or scientific investigation, but a working test for the practical purpose of determining how far the coal could be improved, for subsequent commercial use, by washing, and each washed sample of coal was actually used in a boiler test, so as to compare the results of the washed coal with the unwashed of a similar lot.

In addition to these washing and boiler tests of the large samples we procured some fifty or sixty additional samples of smaller amounts, and these have been examined by means of small scale tests, which perhaps of themselves would not be of very great trustworthiness, but we have repeatedly checked small tests against full scale tests, and in this way have learned to compare one with the other, and interpret the smaller tests in the light of the larger work. I feel therefore that the results we have obtained are thoroughly practical as applied to the whole series of coals from the whole of the Dominion.

We are also carrying out a series of tests on the coking qualities of all of our coals. First we made a series of experiments with a view to developing a method of coking on a comparatively small scale, which would be thoroughly practical. This work has been done at the Sydney and Sydney mine scoke ovens, where we could get large amounts of coal and make large experiments and small tests in parallel, and we have at last devised a method whereby we can make fifty pound lots of coke which are substantially indistinguishable from coke made on a large commercial scale.

We are now engaged on the tests of the western coals by the same method.

Finally the work has involved and is still demanding an enormous amount of chemical analysis. The staff of chemists are under the direction of Mr. Edgar Stansfield, who came to me from the Dominion Steel Company, and who has been working for a little over two years now, first of all perfecting methods, and then carrying out the very important work of chemical analysis on calorimetery determinations on the numerous samples we have had to deal with.

The survey of the coals of the Dominion therefore is almost complete, and while, of course, those of us who have been conducting it wish that it had been possible to do the work even more thoroughly, still we feel that we have accomplished a rather important investigation and I have to thank Mr. Low, the Deputy Minister of Mines, for permission to give you this preliminary statement. The final results will no doubt be put before you before the next annual meeting in the form of a report and a series of appendices containing full details of all tests. (Applause.)

MINE ACCIDENTS.

By E. T. CORKILL, Toronto, Ont.

(Annual Meeting, Montreal, 1909).

The prevention of accidents in mines has been the subject of much controversy, both among mining men and by commissions appointed by the governments of various countries. Most of the commissions appointed have studied the subject chiefly in connection with coal mines, and incidentally touched on metalliferous mining. This has probably been due to the fact that more men are employed in coal mining, and that when an accident occurs in a coal mine from an explosion a large number of men are killed. When this happens the press in every country calls attention to the accident, enlarges upon it, incites the people to the great danger of the occupation, and accordingly the government of the country in which the accident occurs is compelled to instigate an investigation.

In metalliferous mining an accident seldom occurs in which a considerable number of men are killed, the fatalities usually being one or two at a time, though in the course of a year they may amount to a large total. Public opinion is, therefore, not aroused; the management of the mine is not so impressed with the importance of careful supervision; the miners are aroused for a few days, and then forget, and the same conditions prevail as before. It is a common belief among most metal miners that the fatalities in coal mines far exceed those in metalliferous mines. This is a great mistake, and, while it is not proposed to argue that metal mining is as hazardous a calling as coal mining, still the writer desires to impress upon all metal miners that only care and close supervision of their work will lessen the number of accidents and place metalliferous mining on the list of the less hazardous occupations. In the United Kingdom the death rate per thousand men employed in 1907 in metalliferous mines was 1.08, while in the coal mines for the same year the death rate was 1.46 per thou-

sand. The average death rate for the ten years from 1898 to 1907 in the coal mines was 1.40 per thousand, and in the metalliferous mines for the same period 1.14 per thousand. This shows that .26 more men per thousand were killed in the coal mines than in the metalliferous mines. In the German Empire the death rate in 1906 in coal mines was 1.70 per thousand men employed, and in metalliferous mines 1.29 per thousand. In the United States in 1906 the death rate in coal mines was 3.21 per thousand, while in the same year in metalliferous mines in the States of Colorado, Michigan, Missouri and Montana, the death rate was 3.22 per thousand. This shows that the percentage of accidents in metalliferous mines in these states is slightly greater than in coal mines.

The necessity for action to prevent accidents in metalliferous mines in the United States was recognized by the American Mining Congress at their annual meeting in November, 1906, when a committee was appointed to prepare a law suitable to modern conditions governing quarrying and metalliferous mining, with the view of its adoption by the American Mining Congress and recommendation to the various states of the Union for its passage as a uniform law replacing existing laws, which in the best cases were more or less imperfect and out of date. The laws of the states of Colorado, Missouri, Montana and New York, were published by the Congress, to enable those concerned to criticise the existing laws and thereby assist the committee. No uniform set of laws has as yet been adopted by the Mining Congress. In Canada, the provinces of Nova Scotia, Quebec, Ontario and British Columbia have regulations controlling the operation of metalliferous mines. In the Transvaal in 1905 a commission was appointed to enquire into and report upon "The use of winding ropes, safety catches and appliances in mining shafts." The report of this commission was published in 1907, giving in detail the result of their enquiry. Different commissions and boards of enquiry have been appointed in the United Kingdom since 1855 and some of these commissions have investigated the cause of accidents in metalliferous mines, and laws have been enacted to prevent certain dangerous practices. As a result the death rate in the United Kingdom in metalliferous mines is practically the lowest of any of the countries in which metalliferous mining is a considerable industry.

Accidents in mines may be classified under three headings, namely:—

1. Unavoidable accidents that are inherent to the nature of the work.

2. Accidents due to carelessness, negligence or incompetence on the part of the management.

3. Accidents due to carelessness, negligence or incompetence on the part of the workmen.

An interesting table is published for the year 1906 by the German government, classifying the mine accidents in that country for that period, and indicating the contributory causes as follows:

Accidents owing to danger inherent to the work itself . . .	69.31%
Accidents due to defects in the mine workings.	00.78%
Accidents through fault of fellow workmen.	3.24%
Accidents through fault of injured person	26.67%

This table shows a most satisfactory state of affairs in the case of the German mines, since .78% only of the accidents were the results of defects in the working. It is a condition which might quite readily be attained in our mines in Ontario, but only through the active co-operation of all the mine managers in the Province.

In Ontario in 1908 the total number of accidents was 69, resulting in 46 fatalities, of which 38 occurred below ground and eight above ground. Of this number 24% of the fatalities resulted from falls of ground; 26% from shaft accidents; 24% from accidents caused by explosives; 8.7% from miscellaneous accidents underground, and 17.3% from accidents on the surface.

The following table shows the cause and place of the fatal accidents in Ontario in 1908:—

Falls of ground.		11
Shaft accidents—		
Falling from bucket while riding contrary to Act . .	5	
Things falling part way down shaft	1	
Falling into shaft from part way down	2	
Things falling from surface down shaft	1	
Cage accidents	2	
Riding on skip	1	
	——	12

Accidents from explosives—		
Picking into old hole in which explosive has been left	1	
Drilling into bottom of old hole	4	
Picking into explosive in muck	1	
Premature explosion	5	
	——	11
Miscellaneous accidents underground—		
Suffocation from gases resulting from blasts		4
Accidents on surface—		
Machinery accident	1	
Struck or run down by train	3	
Boiler explosion	1	
Explosion in rock house	1	
Miscellaneous	2	
	——	8
Total for 1908		46

Of the total number of accidents, 32 occurred in the Cobalt area, resulting in 30 fatalities.

From a close analysis of the fatalities in Ontario in 1908 it is found that 45.7% resulted from danger inherent to the nature of the work, 32.6% through neglect or carelessness of the management, 8.7% through the fault of a fellow workman and 13% through the fault of the injured person.

In the gold mines of the Transvaal in 1906 there were 815 employees killed. The deaths resulted from the following causes:

Explosives	199
Overwinding	15
Travelling in cage or skip	47
Struck by cage, skip or hauling rope	47
Travelling by ladders	14
Falling in shaft and excavation	67
Falling of materials	59
Fall of ground	198
Inundation by water	55
Winding ropes and connections	37
Tracks and tramways	17
Boiler and steam pipes	9

Machinery	16
Electricity	6
Miscellaneous	29

This is a death rate of about 5 per thousand men employed.

In the metalliferous mines in Spain in the same year, the total number killed was 272, or a death rate per thousand men employed of 2.30%. These fatalities were apportioned as follows:

Fall of ground	70
Explosion of fire damp	3
Blasting	29
Suffocation	7
Inundation of water	1
Falling down shaft	37
Breaking of machinery	61
Miscellaneous	64

In four of the chief mining states of the United States in 1908 the following table shows the number of fatalities:

	Persons employed.	Deaths.	Deaths per 100 employed.
Colorado	34,790	82	2.36
Michigan—			
Houghton County	16,506	44	2.67
Marquette	5,840	22	3.77
Missouri	13,233	51	3.85
Montana	15,000	52	3.47

Mine operators wish to classify a large proportion of the number of mine accidents as unavoidable. It is quite true that a number of accidents do come under this heading. Certain accidents from explosives are very difficult to guard against; but, even from explosives, ignorance and carelessness are responsible for the greater number of the accidents. Possibly one of the greatest dangers, difficult to guard against, is the fall of large blocks of ground, blocks that the ordinary scaling test of sounding will not detect. While sounding is a safe test for small pieces of loose ground, the foreman should see that the walls and roof are watched very closely for any sign of cracks or fissures in the rock. Shaft accidents are in the majority of cases inexcusable.

ACCIDENTS FROM FALL OF GROUND.

These are a class of accidents that are all too frequently classed as "unavoidable," but the responsibility for such rests both with the management and with the men. The management affirm that they always delegate their best men to do the scaling, and as they are usually the machine men and have to work under this ground, they will naturally wish to protect themselves. Superficially considered this would appear to be a sound contention; but miners who have worked underground for years often come to regard the dangers of the occupation with contempt. Moreover, when the scaling should be done and in addition the drilling required of a shift, they are not likely to waste any more time away from their machine than they can avoid. Hence the poor mucker is generally the victim, for the statistics show that this class of labour usually suffers the most from falling ground. In some mines it is found that the stopes are worked in such a way that it is almost impossible to keep the back properly scaled. This is due at times to the greediness of the company in attempting to save money in carrying their levels too far apart for safe working, and at other times to the method of working which makes the scaling of the roof practically impossible. In some mines supervision of the scaling of the stopes is so lax as to be absolutely useless. The manager relies on the superintendent, the superintendent on the foreman and the foreman on the men. The foreman or shift boss cares more about making his hoist of ore large than he does about safeguarding the employees. It is often the practice of the superintendent to get the shift bosses "running" each other to get out the largest tonnage, and consequently they each try to throw the burden of scaling on the opposite shift, with the result that it is not done at all or else done very superficially.

In a low grade mine tonnage is the big factor. The breaking down of floors on the level, leaving men working under a hanging of probably two, three or four hundred feet, which has not been scaled for years, and is, in fact, impossible to scale properly, is sacrificing human life to commercialism. The mucker is, as a rule, in this country, at present a foreigner, usually lacking in sufficient intelligence to "size up" matters for himself. He

has therefore to depend altogether on his fellow workmen in the mine to protect him, and this protection is not as a rule very great.

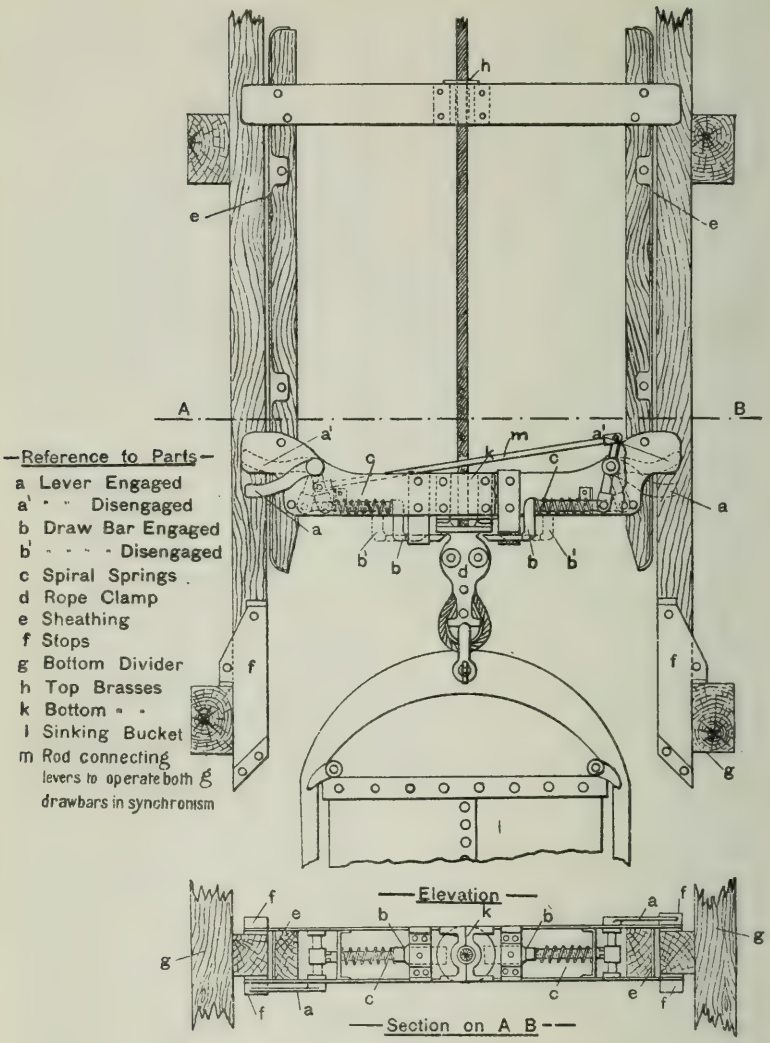
SHAFT ACCIDENTS.

In Ontario, during 1908, this class of accidents represented 26 per cent. of the total fatalities. These accidents occur chiefly from carelessness and violation of the recognized principles of safety in mines. The most prolific source of shaft accidents is bucket-riding. All of the accidents in Ontario from bucket-riding during the last five years have been caused by men riding in the bucket, not when sinking was going on between levels and the men were riding away from blasts, but when riding to and from work on the level. The mines in Ontario are for the most part shallow workings where buckets are used, and the men, therefore, have no excuse for taking any unnecessary risk. The accidents are nearly all due to negligence on the part of the superintendent in enforcing the rules. Some superintendents attempt to excuse themselves by saying that it is impossible to prevent men from riding on the bucket. Such excuses are inadmissible and are merely a subterfuge to shirk responsibility. The practice of riding on the bucket while sinking shafts between levels is allowed by the laws of most countries, provided a chain ladder is always hanging in the shaft as an auxiliary means of escape. Very few accidents result from this compared with riding the bucket from the levels. The use of crossheads in shafts has been condemned by a large number of mining men; but in several countries where inquiries have been made into their use, the consensus of opinion has been that the danger was lessened by the use of the crosshead, provided it was equipped with a safety appliance to prevent it hanging up in the shaft. The writer considers that where crossheads are used they should be either fastened so that they could not leave the bucket or else equipped with an approved safety appliance. In the Transvaal, the Berry safety catch, shown in the accompanying sketch, has given satisfaction.

Accidents resulting from men falling into shafts both from the surface and from the levels are too common an occurrence. The necessity of maintaining guard rails at shaft entrances at all

levels of the mine cannot be too much emphasized. Not only should superintendents have all levels so guarded, but they should also see that the guard rails are always kept in position when the shaft is open. This need of guarding shafts is also applicable to winzes and stopes. When men will not or cannot protect themselves, it is the duty of the employer to protect them by all possible safety appliances. Another danger in shafts is from material falling into the shaft either from the surface or from part way down. These accidents are practically all due to carelessness on the part of someone. Shafts in some instances are improperly protected by doors at the surface so that material is liable to fall down the shaft when the bucket is dumped. Another danger is leaving cars or trucks on the track near the shaft entrance at either the surface or level when a slight push or concussion from a blast would cause them to move along the track into the shaft. Guard rails should always be of a sufficient height at the levels to stop any truck or car. Another danger is from loading material such as steel or timber into a bucket while it is hanging in the open shaft, or from carelessness in fastening them in the bucket. When a bucket is used, material should never be loaded into it unless it is resting on a door over the shaft or swung clear of the shaft, for even a careful workman is likely to make a mistake on occasion and allow material to drop into the shaft. The men working in the shaft are at the mercy of the men on surface, and any careless act should be most severely punished.

Cage accidents happen from a great many causes, the most dangerous being overwinding or the breaking of the cable. This has been a subject of much inquiry in those countries where mining is carried on at considerable depth. The chief accidents we have to contend with in Ontario are carelessness in giving signals and in getting on and off the cages. In shallow workings it is a question whether permitting the men to ride on the cage does not contribute to the dangers of the occupation. Workmen are careless, foremen are careless. Why should they be allowed to endanger their lives any more than is necessary? Another practice which is fruitful of accidents is allowing men to ride on the cages with cars loaded with steel, timber, &c. These are liable to be jarred loose and catch in the timbers, causing a serious accident at any time.



—The "Berry" Safety Catch—

For Crosshead Guide of Sinking Bucket

— Wide Compartment —

ACCIDENTS FROM EXPLOSIVES.

The most prolific source of accidents from explosives is picking into them either in old bottoms or when lying loose in the muck or drilling into old bottoms. In shaft sinking there is a considerable danger from this source which is unavoidable and this very fact should lead to increased caution. The driller firing a round of holes in a shaft should be very particular in counting the reports, and if there are any reports short, this should be reported in person to the next shift, who should also be notified just where the holes were drilled, so that in mucking out, due caution may be used in picking up the bottom. The old theory held by some miners, that if the exploder is taken out of the hole there is no danger, is a misconception, and miners should be so taught. Superintendents and foremen, who fail to instruct the men under them properly, or who neglect to see that the men exercise due care, are much to blame for accidents arising from this cause. Accidents occasioned from picking into a loose explosive which has got into the muck from a cut-off hole are difficult to guard against. A wise precaution when dynamite is used is either to take the wrapper off the dynamite cartridge or to slit it so that if the dynamite does get into the muck it disintegrates, and is so scattered that sufficient does not remain in one spot to do damage. Another safeguard is to keep the muckers from using the pick too strenuously. It is as effective when mucking in drifts to use the pick for pulling the muck down, as to sink it up to the eye, to the great danger of the workman. The latter practice is simply energy uselessly expended.

Another source of accident is the introduction of an explosive with which the men are not familiar. This is especially true in the cold weather when the explosive requires to be thawed. Dynamite is the explosive to which long use has accustomed all miners. When thawing it they gage its readiness for use by its pliability. Other explosives, such as gelignite, even when pliable may not be properly thawed, and in fact the latter is fairly soft when partly frozen. In the condition near its freezing point, gelignite is most dangerous, as is also dynamite. Superintendents should see that all explosives are in the thawing house, exposed from 4 to 6 hours to a temperature of 85 to 90 degrees F. If warm water is used, the temperature of the water should not be

above 125 degrees F. Care should also be taken that the explosive, should not be removed from the thawing house in cold weather until the miner is ready to load his holes.

In Ontario last year five men were killed by accidents classified under the head of premature explosions. These can only be caused by the fuse running if the holes are properly loaded and tamped. Quick fuse is responsible for a very small percentage of the accidents attributed to premature explosions. The chief reason is not tamping the holes, thus allowing the fuse to spit into the hole. Another reason is carelessness with lighted candles or from smoking while the holes are being loaded. The writer has known of instances where a snuff from a workman's candlestick has fallen into the drill hole when it was partly loaded. Such accidents are generally attributed to quick fuse, as the man very seldom survives to tell how it happened. It is, however, recommended that both high grade fuse and caps be used, and if found satisfactory that no change be made. The men get used to one brand of fuse, the length of time it takes to burn, and govern themselves accordingly. The use of different brands which have different speeds of burning will confuse the workmen. It would be a step in the right direction if manufacturers were compelled to make a fuse that would have a burning rate between certain limits.

Some miners, and even foremen and superintendents, have the idea that if a hole has exploded it is perfectly safe to drill into it. The foreman who orders men to do so is taking criminal chances, and the men that do so of their own accord are tempting fate. Still, many accidents happen as a result of such foolhardiness. How can men be expected to avoid this risk when those in charge will permit it or order it done?

A serious accident from suffocation occurred in the summer of 1908 in a 50-foot shaft near the Montreal River. The accident took place at a time in the summer when the atmospheric conditions were such that the gas from the explosives used in blasting hung heavily in the shaft. At such time increased care should be taken by the workmen to get the gases out of the shaft before entering it, no matter how shallow the workings. A little care taken in running the bucket up and down the shaft will generally clear it of impure gases. Some authorities suggest a spray of

iron sulphate solution as a means of getting rid of poisonous gases from explosives. This might be applied with success in long drifts in mines, in which, by reason of their length, the gases hang heavily after an explosion.

Accidents on surface are generally due to carelessness or from the lack of reasonable precautions. Boiler explosions, if the boilers have been kept properly cleaned and regularly inspected, are nearly always due to insufficient water.

Accidents to workmen caught in machinery in power houses, smelters or concentrators, are nearly always attributable to the fault of either the workmen themselves or to the neglect of the management in neglecting to properly guard the machinery.

CONCLUSION.

A study of the detailed returns of mine accidents in Ontario, during 1908, will show that while some of the accidents could not have been avoided by reasonable human foresight, others were attributable to such causes as improper mining methods, failure of appliances, lack of proper supervision, and carelessness or ignorance of the miners. It has been suggested, and the writer believes it is the practice in some mining camps, for the mine managers to turn over for prosecution to the civil authorities any workman who is guilty of a dangerous act. This might be a good practice and under the present law could be done by laying information before the Inspector or Crown Attorney; but in a number of cases the foreman or superintendent would rather shield the guilty party, than lay information against him, if he happens to be one of their best workmen.

Lack of discipline in the mines, particularly in the Cobalt area, and lack of supervision are the two chief causes for a large number of accidents there. When we consider that 32.6% of the accidents, which resulted in fatalities in 1908 in Ontario, were caused by neglect, carelessness or incompetence of the managements, we are presented with a condition of affairs obviously requiring radical improvement. A lack of discipline and supervision, besides increasing the dangers of the work, must necessarily indicate a lack of mine efficiency and so influence

detrimentally the cost of the output. This lack of supervision often results in some of the workmen being permitted to go underground while under the influence of liquor, when they are both a danger to themselves and those working with them. A fatal accident in the mine, apart from the fact that a life has been sacrificed, is very expensive for the mine itself. The whole mine force is disorganized for the time, the men are affected thereafter by the further thought that another accident may happen, and this decreases the efficiency in their work, while the costs of suits for damages brought by the relatives of deceased workmen, add to the total cost of the accident. The total loss to the company from a fatal accident would in most cases pay several times over for maintaining the mine in a proper manner, and for the adequate supervision of the mine workings. Why should the manager of a mine depend altogether on those under him for the safety of the mine workings? Is it not his duty to inspect those workings personally and see that the mine is in a safe condition for his workmen? If he does not do this often, how is he to know that the superintendent and shift bosses are doing their duty? In a number of cases it is to be feared that shift bosses spend so much of their time inspecting a soft seat in the boiler house or a warm spot alongside the pump that no time is left to properly supervise the work in the mine. It is not claimed that our mines do not have enough officials, as in some cases there are possibly too many and the work is shifted from one to the other until no one does it properly, but I do contend that the managers in a number of cases do not personally see that the mining work is properly looked after by their assistants.

There is no doubt that in a "boom" camp such as Cobalt has been during the last three years, there is a spirit of feverish speculation and unrest that tends to the disorganization, lack of discipline and loss in efficiency of both the men and those in charge. The excitement of stock speculation and the prospects of making money through the staking of claims, and the buying and selling of claims is of too interesting and remunerative a nature to be allowed to pass for the sake of devoting their entire time to overseeing the work at their mine. A careful foreman, a conscientious superintendent and a vigilant manager, who try to guard against all possible accidents and are always on the alert to prevent

them, will, in time, instil into the minds of the men a like degree of care and regard for their own safety; while on the other hand if they are careless and reckless about the work of the mine they can only expect their men to be the same and have themselves to blame if the men do foolhardy things. It should be the first care of all mine managers to keep their mines in as safe a condition as possible. If this is done a higher degree of efficiency can be obtained as the manager can gather around him the very best miners and keep them.

In presenting this paper, the writer has attempted to direct the attention of the mine operators in Ontario to the prevalence of mine accidents and to call particular attention to those accidents that have occurred most frequently in the mines of Ontario in 1908, in the hope that a little thought and discussion on these dangers will cause the mine operators to study the accidents and their causes and make a combined effort to eliminate the sources of danger and thus lessen the list of victims who have to pay with their lives for the development of the mineral industry of Ontario.

DISCUSSION.

Mr. Strangways: In connection with this paper I would like to call attention to the fact that about sixty per cent. of the accidents, either in coal mines or metal mines, are due to faulty roofs. Now, this matter can easily be controlled by the superintendent or foreman of any mine. When we come in contact with foreign labour such as Finns and Poles, it is only by the utmost care on the part of the superintendent that accidents can be prevented. I know personally day after day I used to go down and find the tram was working under a bad roof, and we would get the machine men to take it down. The machine men were under orders all the time to take down a bad roof, but unless they are closely watched they will neglect to do so.

MR. CORKILL:—Mr. Strangways has stated that sixty per cent. of the accidents in both coal and metal mines are due to faulty roofs. This is certainly not the case in Ontario, as last year but twenty-four per cent. of the accidents were from this cause. Of this number, twenty-five per cent. were killed in one accident, caused by a large block of ground falling. An accident such as this is the most difficult to guard against, as in some cases it is almost impossible to see that a roof is in a dangerous condition. Of course when anyone is hurt in any of the drifts or crosscuts in the mines of Ontario from falling ground, it certainly is their own fault or the fault of the men in charge.

MR. BROCK:—I would like to ask where Mr. Corkill draws the line between the responsibility of the management and the responsibility of the miner.

MR. CORKILL:—It is practically impossible to set a hard and fast rule as to where the responsibility of the management ends and the responsibility of the workmen begins, in fact in some countries the management are held responsible for all accidents. The management too often try to shirk this responsibility and shift it on the men, saying it was the fault of the men that the accident happened, when the shift boss should have been on hand to see that the working place had been made safe before the men had begun work.

Several years ago, while working in the mines, I could easily see that the practice the foremen adopted with regard to scaling was very superficial. In one particular mine they had a gang of men scaling every Sunday and the shift boss was supposed to be on duty. He was on duty in the morning, but you would not find him there for half an hour during the whole ten hours. I am afraid that in a number of the mines that is the custom—too much the custom. The shift bosses tell their machine men to look after it, and then let it go at that, saying that as they have to work underground they should attend properly to the scaling.

MR. LINDSAY:—I think that the author of this paper will find that when the district about which he is speaking gets a little older in mining, that the main difficulty he will have to contend with will be carelessness on the part of the men. In British Columbia the Workmen's Compensation Act is in operation, and

any workman injured in the mines receives a compensation of $1,500, whether he is responsible or not for the accident in question. In the Crow's Nest Company's mines, out there, we have done everything that can possibly be done by human ingenuity to reduce accidents, so far as supervision and proper mechanical appliances are concerned, and still we have a great many accidents. We report every accident to the Government of British Columbia, so that you can get statistics there as to exactly what has happened in the mines in the way of accidents. During the last six months we have had about six hundred accidents, a very large proportion of which were entirely attributable to negligence on the part of the men. It is a difficult matter to cope with. The miner, as a rule, is naturally negligent, and it is a fact that the injuries in the mines in a great number of cases have arisen from the neglect and carelessness of the men themselves. Of course it is exceedingly difficult to prove that before a Court of Justice, but where you have an immense amount of movement in a mine with three or four thousand tons of coal a day, and an immense amount of roof to take care of, accidents will happen, but the great bulk of them might be avoided if the men themselves were more careful.

MR. FRALECK:—I think, Mr. President, that this is not a paper that we can pass over lightly. As the paper stands in its present form it constitutes a very serious indictment indeed of the mine superintendents and mine managers and mine operators in the Province of Ontario. Now, sir, no mine superintendent, no shift boss, no foreman or operator can complain if that indictment is justified. Mr. Corkill is in possession of the facts to a larger extent than we are, but I would like to bring before the meeting one fact, and that is that no mine manager or superintendent or shift boss is possessed of such omnipotent power that he can make men do exactly what he tells them to do. To my mind that is the whole trouble. The power of the superintendent is so limited that when a man disobeys his orders or is careless and endangers his own life and the lives of his fellow workmen, the only recourse in the hands of the superintendent is to discharge that man, but I hold that the simple discharging of a man does not constitute any punishment to that man for his carelessness.

It may be in remote camps where you are isolated and where a man has to go to considerable difficulty and expense in getting another job; but take for example the Cobalt camp, as it is situated to-day—any man in that camp, especially if he is a good workman, knows perfectly well if he is discharged to-day he can get a job somewhere else to-morrow. That is the condition of affairs there. I would be overjoyed if the Department would adopt the course suggested by Mr. Corkill in his paper. If a man is careless or negligent and if he disobeys orders to such an extent that he kills or injures a fellow workman, or through his negligence a fellow workman is killed or injured, or if he endangers the life of a fellow workman, the Department should prosecute that man, and that would result, I am satisfied, in reducing the number of mine accidents by at least forty per cent. In the ordinary affairs of life—in the business of great corporations –in the exercise and conduct of a railway, if a switchman leaves the switch open and an accident results, he is indicted for manslaughter. In order to cut down this accident rate, the mere action on the part of the Department would be sufficient in these cases where fatalities result. There should be some penalty in cases where any fatality results, or where fatalities have resulted by the carelessness of the workmen, as I understand there is no legal machinery in our country to meet a case like that. The mining superintendent of course does not want to have accidents. It is one of the hardest things that ever comes to the ears of any superintendent or mine manager, and yet there are cases of that kind constantly occurring. There is one case in point that I know of where a man by his negligence caused the death of another man, and the only punishment was to discharge him. He was discharged from his position and immediately went over to another mine and got a position of running one of the little hammer drills at $3.50 on a nine hour shift, and in his former position he had been earning only $2.50 a day. If that man could get the same rate of increase he would be willing to kill a man every minute if he got off in that way, and that is the condition of affairs as I understand them under the present legal procedure.

MR. CORKILL:—I must correct Mr. Fraleck in regard to that. If he studied the Mining Act more closely, he would see that

the Act as it is to-day imposes a penalty for infraction of the law on both the workmen and the management, still the penalty is not sufficient. This will probably be changed and an adequate penalty imposed. The law states that no action can be taken except by the District Crown Attorney or the Inspector. All that the mining companies have to do is to lay information against any of their workmen guilty of carelessness, and if they can furnish the proof, I am sure the Crown Attorney or the Inspector would be only too glad to act upon it.

Mr. Fraleck says he would be overjoyed if the Department would prosecute the workmen for any act of negligence whereby a fellow workman is killed or injured. That may be very well in theory, but how will it work out in practice? The Department cannot have officials in all the mines to see if the men are careless in their actions. The time to stop this practice is before the accident happens, not after when too late to save human life. The management allow these careless practices to go on for months until someone is caught, and they then say that if the Department would only prosecute the cases the accidents would cease. How can the Department help matters unless the management of the mines will lay the information against these careless workmen? This they will not do, particularly if he is a good workman. They prefer to take the chances of having someone hurt, rather than run the risk of losing their good workmen. They will, however, be among the first to say: Why does not the Department punish these careless workmen who endanger the lives of their fellow workmen?

Mr. MacDonald: —I am a miner. I heartily sympathize with Mr. Corkill's views. Every sentiment expressed in his paper is irreproachable in my estimation. The fact of the matter is that mine operators the world over pay little or no attention to the kind of men they employ to actually work in the mines. That is the trouble. The man who is running the mine ought to know who is working for him, he ought to know his foreman and he ought to know his superintendents. You cannot mine ore with dressmakers and milliners. (Laughter).

Mr. Langford:—Most of my experience has been in India. In the mines in which I was engaged in India there were instituted examinations for the men who were working in different capacities,

and we found that by that means the number of accidents were reduced very appreciably. When these examinations were first instituted, they were not made compulsory, but as a sufficient number of men had passed the examinations which were held by the Government, it became necessary for men in that capacity to hold a certificate from the Government before they could get employment, and eventually it became the law that if a mine manager employed men in any capacity without a ticket he did it at his own risk, and I think it might be advisable to adopt measures of this kind in our Canadian mines.

MR. STRANGWAYS:—I would call attention to the fact that government supervision as regards the most frequent form of accident, viz., that of falling roofs, would not be of much value, because when pieces of more than five to ten tons come down, it is rarely due to any fault on the part of the operators. It is the falling of pieces of ten, twenty, thirty to forty pounds, just before the machine men are setting up and before they scale, that cause the majority of accidents. I would also call attention to another fact, and that is that in Ontario we have not an efficient class of miners, and only ceaseless supervision by those in authority will do any good towards reducing accidents attributable to this inefficiency.

MINING ACCIDENTS AND THE RENDERING OF FIRST AID.

By Charles H. Hair, M.D.

(Cobalt Branch Meeting, December, 1908).

Mining is a dangerous occupation. Accidents at mines will always occur and the number will be in direct proportion to the care taken to prevent them, not only on the part of the employers but of the employees as well. A Mining Act has been enacted with a view to lessening accidents or at least to minimizing the dangers of their occurrence, and of thus protecting employers as well as the men; and while the Act may have its defects, yet on the whole the advantages of its provisions will depend upon the enforcement of the spirit of the Act rather than of its letter. A criticism of the Act is not the purpose of this paper, but perhaps a reference to it will not be out of place. After having spent nearly three years in the Cobalt camp, during which time my professional duties have required that I should deal with a majority of the cases arising from mine accidents here, I have been especially impressed by two outstanding facts:

1. That in many instances, at least, the spirit of the Mines Act has been violated, if not the letter.

2. That a proper estimate of the danger of the miners' occupation seems to be lacking and especially so is this the case among the men themselves.

It is true that in life one becomes accustomed to hazardous risks; that the acrobat, for example, will in time, as it were, defy the law of gravitation; and the miner, in the same manner, beginning by taking a slight risk in some department of the work and going on to disregard greater hazards, finally meets his end. This may be due to negligence on the part of the company, or due to his own or fellow-workmen's carelessness, but generally the number of accidents in a mine will, to a great extent, depend on

the estimate employers, as well as employees, place upon the dangers of the occupation, and upon life itself, and hence protection thereof will be in direct proportion.

Accidents may be classified in the following manner:—

1. Accidents due to neglect or carelessness on the part of the mining company or the employer.

2. Accidents due to neglect or carelessness on the part of the employee.

3. Accidents due to causes over which no one has control—or unavoidable accidents.

Now as to Class 1. The Mines Act aims at compelling companies to take certain necessary precautionary measures to prevent accidents, and it is fairly specific in its details; but it would be interesting to know how posting rules in a shaft-house forbidding men riding up and down in the bucket, when at the same time the men are permitted to do so, will prevent an accident from this source. It is true one will find a number of veteran miners in Cobalt who have ridden in shaft buckets year after year, even before there was a Mines Act, but is their example a good one to be followed by the novice or beginner? This then is one of the risks that are permitted and taken. In the event of accidents from this cause, employers, although they may have posted notices forbidding the practice, will nevertheless very probably be held responsible for their employees' disregard of the regulations.

2. *Accidents due to carelessness of the employees.*—These classes of accidents unfortunately mean a liability to the Company, and often injuries to those other than the offending persons. Perhaps the most numerous class of accidents are those arising in some way from the careless use or disposal of powder, especially in the muck, contrary to the company's orders; and in many other ways the carelessness of employees may endanger the lives of their fellow-workmen. Now, as previously stated, such carelessness may be due to a lack of a proper estimation of the danger or a proper estimation of the value of life; but if a railway switchman is careless enough to leave a switch open and a train is wrecked in consequence, not only is the railway company made liable for damages for the accident, but the man

himself is held criminally responsible for the losses of life. This is as it should be, and in providing against accidents in mines, it should be insisted: (1) that employers rigidly enforce the rule of dismissal for any carelessness on the part of employees; and (2) that offenders in this respect be subject to similar treatment as the law provides for the punishment of criminals accused of endangering the lives of others.

3. *Unavoidable Accidents.*—This class of accidents are much less frequent than accidents attributable to preventable causes.

Danger from Gas.—As underground work advances dangers from gas will become greater, and during the first year of my experience in this field, when a great deal of open-cut work was done, I did not include gas as one of the dangers to be reckoned with. The past year has demonstrated, however, that fatal accidents may result from the presence of gas, and that this is a factor to be considered in future. The main constituents of this gas are carbon dioxide, carbon monoxide, nitrogen, slight traces of ammonia, and the fumes of nitroglycerine. Of these constituents, carbon monoxide is probably the most fatal. Physiologically the cases evidence an overdose of nitroglycerine or the nitrites, the main symptoms of which are dependent upon the amount of gas inhaled. There are two kinds of gas poisoning: acute and chronic. In acute cases "A," where a limited quantity is inhaled; "B" where a considerable quantity is inhaled in a very short time. Symptoms in the acute cases are:—

1. Beating in the head.
2. Flushed condition of the skin, especially of the upper part of the body.
3. A giddiness.
4. Nausea and usually vomiting.
5. Difficulty of respiration.
6. Restlessness.
7. The pulse full and compressible.

When a large amount of the gas is inhaled the symptoms are usually a giddiness, passing into unconsciousness in a short time. After the unconscious period, if the patient recovers therefrom, follows a drowsiness or langour and an intermittent pulse with considerable difficulty in respiration.

In the chronic cases of gas poisoning, where men are constantly inhaling small quantities of the gas, the four main symptoms are:—

1. Slight persistent headache.
2. Cough.
3. Indigestion.
4. Nerve disorders.

A. is mostly due to volatilization of the fumes of nitroglycerine.

B. The gas may be absorbed by carrying the dynamite in the boots or rubbing the face with the hands after handling the dynamite. One instance is quoted of a man having eaten an apple after having cut a stick of dynamite with a knife and the same effects were produced. I am of the opinion, however, that the main symptoms are due to a volatilization of the fumes of nitroglycerine rather than to absorption through an unbroken skin.

TREATMENT.

The first step in the treatment of these cases is very obvious; namely, to remove the patient to fresh air as quickly as possible and if for any reason this is impossible, to force air into the immediate vicinity. This should be followed by keeping the body warm with blankets, but the head cool. The patient should be removed to a room where there is an abundance of fresh air.

2. The effects of gas are usually worse at the change of shifts. Men going on duty have as a rule just had a full meal. In these cases recovery is more rapid if the stomach is emptied. I have found strong black coffee a suitable remedy to give if the patient can be induced to swallow. Coffee has some emetic value as well as being a stimulant, and I therefore recommend it as one of the first aids. So far, if a man were alive when I was called, none of my cases has ended fatally, although I have seen unconsciousness continue for one hour to one hour and a half. If called to a case in which the patient is quite unconscious and I have reason to think the stomach is full and there is no depression, I usually give apomorphine about 1-10 of a grain and this will empty the stomach in about five to ten minutes. Stimulants are usually indicated: if the patient can swallow, diluted alcohol

is usually the best, and undoubtedly atrophine as a drug is the most efficient, especially where there is difficulty in respiration. Often the patient becomes quite uncontrollable and is in danger of hurting himself on the floor unless watched, hence it is necessary to prevent the patient from bruising the head. If the patient shows signs of failing respiration, artificial respiration should be resorted to and this can be done quite easily before the doctor arrives. One point to be observed in artificial respiration is to avoid going through the motions too quickly. The patient's arms should be slowly extended well above the head, and then flexed down on the thorax with slight pressure.

Haemorrhage.—Hæmorrhage usually occurs in clean-cut wounds, hence the more usual forms of wounds, that is, bruises or contused wounds do not bleed freely. However, this is one form of accident where first-aid is necessary and can be readily rendered before the doctor arrives.

Hæmorrhage is of two varieties:—a. Venous, b. arterial. To distinguish one from the other is necessary as the treatment differs slightly. Venous is more of an oozing nature, while arterial spurts and often alarmingly so. In rendering first aid in these cases, the patient should be in a recumbent position. This prevents fainting and often lessens the flow.

2. If arterial bleeding from the arm or leg, elevation of part aids in stopping the flow; but in venous this is not necessary as the blood flows upwards in the veins.

3. In severe cases, place a band or cord above the wound: that is nearest the body, and when venous, both above and below the wound.

4. If this fails to stop the flow, plug the wound with anything handy, except flour—waste material used for wiping machinery will do, or any piece of cotton, and apply pressure in some way, even if it has to be done with the hand. This method is most effective especially from a wound involving the bone, the purpose being that a clot soon forms. If some time must elapse before the arrival of a doctor, the cord tied on the limb should be after a period slightly slackened, since the tight pressure unduly continued is not only very painful but might cause superficial gangrene; besides the clot formed is sufficient to arrest any further flow. If the patient complains of weakness, keep the

head low, and give abundance of water and stimulants if any are at hand. Do not be alarmed at slow bleeding or oozing, it is the rapid flow of blood that does the damage by lowering the blood pressure.

Head wounds.—Scalp wounds are the most numerous form of wounds in a mine, the result as a rule of falling rocks, and usually are accompanied by profuse bleeding.

1. Before the arrival of the doctor it is not advisable to remove the hair from such wounds, as the hair aids clotting and pressure applied is the most efficient method of stopping the blood. This can best be done by the hand, using a towel or any other material. The patient should also be kept quiet in a recumbent position. If the wound is small, and is located on the side or back of the head there is little likelihood of a fracture unless the force came at right angles. The danger in these cases is the possible development of a subdural hæmorrhage and hence a clot on the brain. In treating these, again, keep the patient lying down, apply pressure to the wound, say with a towel or any material handy in such a way as to close the wound, and often this is sufficient to almost close the cut.

Fractures.—This is a form of accident to which first aid can be rendered very readily, as there is very little difficulty in diagnosing a fracture which usually shows considerable deformity of the bone, besides the loss of function. In handling these cases it is best to keep the limb as quiet as possible for every movement of a broken bone means injury to surrounding tissue.

1. The simplest method of doing so is to fasten the limb, without removing the clothing, to a piece of board, covered with a piece of blanket, keeping up extension, the board being long enough to go above the fracture and the joint immediately above or below. The limb can be fastened to a board with a towel or handkerchiefs.

2. Another form of temporary splint is an ordinary pillow. Place the fractured limb on the pillow and bind the pillow around the limb. This is quite a convenient splint when removing the patient over a rough road.

As a rule, if such temporary splints are applied, the patient can be placed on a mattress and at once removed to the hospital;

for if a limb is set and the patient is moved, it is usually necessary to re-set the limb, as travelling jars the fragments.

Eye-wounds from blasting accidents, etc.—1. In such cases wash the eyes with clean boiled water, dropping it on with a piece of cotton.

2. Take a clean piece of cotton or any convenient material, dip it in the clear warm water and cover the eyes, binding the bandage on with a handkerchief. This prevents the action of the lids and hence much less irritation to the small cuts on the corneal surfaces from the particles of dirt. The services of a medical man should then be obtained, for I am convinced that a great deal of the corneal ulceration from these wounds depends upon the early and prompt use of eye antiseptics. Boracic acid solution and an application of a 10% argyrol solution are the most efficient.

In conclusion, the importance of the prevention of shock should be noted. Shock is one of the systematic conditions which is not only hard to explain but hard to prevent. When, however, an accident occurs of a serious nature this procedure should be followed.

1. Place the patient in as warm a room as possible.
2. Keep the patient lying down.
3. Allow the patient water to drink, diluted whiskey or alcohol, if any is at hand.
4. Do not allow too many other persons in the room in which the patient is placed.
5. Prevent, if possible, the patient learning of the seriousness of his accident.

THE GEOLOGICAL INVESTIGATION OF CLAYS.

By HEINRICH RIES, Ph.D., Ithaca, N.Y.

(Annual Meeting, Montreal, 1909).

Prospectors and engineers in their search for mineral products commonly bend their energies mainly towards the locations of metalliferous deposits, especially those containing nobler metals. This appears natural since these have a greater market value and often afford a larger reward when found.

Partly also because of the greater popular interest which these metals arouse, and because of their greater market value it is this group of resources to which Geological Surveys, whether Federal, Provincial or State organizations, have given primary attention, when undertaking economic work; non-metallic products such as coal, natural gas, etc., coming in for secondary consideration, while still others are often neglected for a long time.

To this last class of more or less neglected mineral resources belongs clay, material which for many years was given but scant attention by surveys and economic geologists, probably because its worth and usefulness were not fully appreciated. It is indeed true that this material as it comes from the ground has but little value as compared with gold and silver, but still the value of the crude material per ton in the case of good grades is easily comparable with that of iron or coal, and in the case of the higher grades often exceeds them; but even assuming its intrinsic value to be comparatively small it is nevertheless undeserving of the neglect which it has received, being really of great worth, because of its extreme usefulness, and (I may even say without appearing prejudiced) of an almost indispensable character in many branches of the industrial art.

To illustrate briefly: As a structural material its widespread use is but too well known in the form of common and pressed brick, terra cotta, floor and wall tile, etc.; as a refractory lining

for furnaces, clay in the form of fire-bricks is used in enormous quantities because of the heat resisting qualities of these materials and their cheapness as compared with other forms of refractory linings; again for paving, fireproofing, electric insulation, table use, etc., etc., burned clay is used in large amounts and in many cases has no good substitute.

This importance of a common material may perhaps be further emphasized by the statement that, in the United States alone, the annual value of the clay products produced in 1907 amounted to $158,942,367.00, and was exceeded only by three other mineral products, pig iron, coal and copper, while the two following it were petroleum, valued at $120,106,749.00, and gold, valued at $90,435,700.00.

Among the clay products, brick for building purposes form a considerable proportion (about 67 million dollars worth) of those in 1907, and while their selling price may not be comparable with that of products like iron, copper and gold, they make up for lack of intrinsic value, by giving employment to a large number of workingmen. Thus of the $159,942,367.00 given as the value of clay products in 1907, about 40% of this, or $63,000,000.00 was expended for labourers' wages. In other civilized countries the demand for this group of products is equally large, and if they are not manufactured within the area of consumption their deficiency has to be supplied by importation. As an interesting example of this we may take the case of the Dominion of Canada, and in the table at the end of this paper are shown the statistics of production for the year ending March 31st, 1908, these figures having been kindly supplied me by Mr. R. W. Brock, Director of the Geological Survey.

Looking over this table, we find that the value of the clay products imported into the Dominion during the period mentioned amounted to three and one-half million dollars, while from the statistics of production given in the reports, we find that the value of clay products produced within the Dominion during the year 1907 amounted to $5,752,318. The value of the imports there was about 60% of the value of the domestic production, and indicates clearly to what a large extent Canada is at present dependent on other countries for products manufactured from clay.

Many of the clay products which are now imported into Canada, could, no doubt, be made within its boundaries, for it surely is not completely lacking in clays of value, and the search for them as well as the demonstration of their occurrence and value should form a most fruitful field for investigation. Such an undertaking, however, should be carried on in the most efficient manner and yield results which are of the greatest value to the consumer of the raw materials. It, therefore, brings up the question of what should be included in a geological investigation of this class of mineral resources. Indeed the selection of the proper methods is of prime importance since, as I have said above, it must be remembered that the data must be placed in such form that they will serve the manufacturer of clay products. If the work is only partially done the results may be well nigh worthless.

The first step in an investigation, such as that referred to, involves the mapping of the clay or shale deposits together with a statement of the thickness, extent, irregularities, physical impurities and location with regard to shipping facilities. Some clays can be pronounced as worthless upon superficial examination, because of their location or glaringly inferior character, while others can only be passed upon after a careful study. Low grade clays are commonly manufactured on or close to the spot where they are dug and the low price of the product usually prohibits long hauls to market, except possibly by water. High grade clays, on the other hand, as is self-evident, can in their burned and even sometimes unburned form be shipped a considerable distance to market, especially if they are in demand. A most striking case of the latter was noted by the writer last summer in British Columbia, where Pennsylvania coke-oven brick were being used at a delivery price of over 55 dollars per thousand. One naturally pauses to ask whether the presence of clays for this purpose cannot be demonstrated within the Dominion, but as I have already intimated the mere proof of the field occurrence is not sufficient, nor will mere inspection of a clay settle its value or uses.

One cannot determine its characteristics without further examination. The ore miner does not pass upon an ore without first having it assayed, nor does the consumer of coal for metallurgical purposes accept the product without knowing something

about its analysis, and so the consumer of raw clay must have further data regarding the material, than the mere statement of the size and location of the deposit. It is here, however, that we find evidence of much misdirected energy. In many instances where geological investigation of clays has been made the field work has been supplemented simply by chemical tests. This I venture to say is a mistake, because in the majority of cases very little information can be gained from a mere statement of the quantity of silica, alumina, iron, lime, magnesia and alkalies which the clay contains.

This is so for two reasons. Firstly, an analysis of the type mentioned above gives us little or no information regarding the physical behaviour of the clay (a matter of prime importance), and secondly, some substances such as SO_3, FeO, organic matter and TiO_2, which exert an important influence on the behaviour and uses of the clay are very rarely determined. I do not wish to argue from this that the chemical analysis should be abandoned altogether, for in the higher grades of clay it may be of value, and in addition some interpretations can be made from it. Moreover if carried out in the rational form it may be valuable. But unfortunately our present methods for making this type of analysis are not thoroughly satisfactory. A much more important aid or supplement to the field work is the physical examination of the materials.

Samples carefully taken in the field should be studied in the laboratory to determine their physical qualities. We must know the amount of shrinkage which they undergo in drying and burning, the colour and density to which they burn at different temperatures. The amount of heat they will endure, their plasticity, etc. These are all data which the clay worker wishes to know and which give important clues to the application of the material, clues that no amount of chemical analysis may have shown.

This brings up a question asked by many: Have we no way of testing a clay in the field? Cannot a geologist carry a portable furnace about with him, as a plumber does his stove, and test his clay right on the outcrop in the course of a few minutes? This question must, I fear, be answered in the negative for such a furnace would need to be so small that the small sized test pieces necessary for it would yield unreliable results, and

moreover a fire test would have to be carried on so rapidly as to yield very different results from those obtained by slower firings made in the laboratory under proper conditions, or even in practice.

It will be realized therefore from what has been stated that an economic geologist's study of a clay-bearing area should embrace, first, a careful examination of the material as it occurs in the field, and secondly, a supplementary laboratory investigation, mainly of a physical character, but also a chemical investigation where the occasion demands. These two sets of data will then furnish a report which can be intelligibly used by the clay worker.

The Canadian Geological Survey has always been in the foremost rank of those North American Surveys which have laid special emphasis on economic work, and I trust we may look forward to its taking up the problem of its fictile resources at no very distant date, for it would surely seem as if many of the Pleistocene areas of Southern Canada, the Carboniferous formations of Nova Scotia, or the Cretaceous beds of the West, as well as others, might contain valuable plastic resources which could be drawn upon as an important source of domestic supply.

Statement showing Quantity and Value of Bricks, &c., and Earthenware, &c., imported into Canada during the Year ending March 31, 1908, with portions taken from Great Britain and United States respectively. (From Canadian Returns).

ARTICLES IMPORTED	Year Ended March 31, 1908.					
	Total Imports		From Great Britain		From United States	
	Quantity	Value	Quantity	Value	Quantity	Value
Bricks, Clays, &c.:—						
Bricks, fire, of a class or kind not made in Canada		$639,347		$149,935		$488,034
Bath bricks		1,845		1,710		135
Building bricks.....M.	13,800	139,185	862	17,432	12,938	121,753
Paving bricks.....M.	5,340	61,346	2,678	39,462	2,662	21,884
China clay, ground or unground.....Cwt.	257,768	97,236	172,562	58,544	85,206	38,692
Fire clay, ground or unground		155,873		26,309		129,513
Manufactures of clay, n.o.p.		110,141		24,640		84,850
Pipe clay		319		151		168
Clay, all other, n.o.p.		14,292		590		13,693
Drain tiles, not glazed		2,080		491		1,589
Drain pipes, sewer pipes, and earthenware fittings therefor, chimney linings or vents, chimney tops and inverted blocks, glazed or unglazed		125,747		21,619		104,128
Total bricks, clays, &c.		$1,347,411		$340,883		$1,004,439
Earthenware and Chinaware:—						
Brown or coloured earthen and stoneware, and Rockingham ware		$ 22,688		$ 10,620		$ 9,545
C. C. or cream coloured ware, decorated, printed or sponged, and all earthenware, n.o.p.		238,317		168,438		28,016
Demijohns, churns or crocks		16,456		4,500		11,380
Tableware of china, porcelain, white granite or ironstone ware		1,565,806		1,051,482		31,701
China and porcelain ware, n.o.p.		112,227		29,394		10,874
Tiles or blocks of earthenware or stone prepared for mosaic flooring		45,759		13,237		27,587
Earthenware tiles, n.o.p.		116,480		45,055		66,617
Manufactures of earthenware, n.o.p.		84,594		36,359		28,769
Total earthenware		$2,202,327		$1,359,085		$214,489

Department of Trade & Commerce, Ottawa, November 14, 1908.

WHAT IS AN ORE?

By J. F. KEMP, D.Sc., Dept. of Geology, Columbia University, N.Y.

(Annual Meeting, Montreal, March, 1909.)

The definition of a perfectly familiar word sometimes involves unexpected difficulties when we are confronted with the necessity of its expression in unmistakable language. The more familiar the object noted by it, the greater is the surprise of one who finds himself obliged both to delimit from everything else and to put into other words the essential characters. Nothing is more familiar to the mining fraternity than the word "ore." So familiar is it that not every writer of a book on a mining subject has even thought of its definition, having obviously taken for granted the fact that everybody knows what ore is. There are nevertheless some striking differences to be found in the published works, and it may not be without interest to set the matter before the Canadian Institute and see what the impressions of its members are upon the subject.

The variation in conceptions of ore largely rests upon the double use of the word, both in a purely scientific and in a technical sense. Sometimes this contrast is not fully appreciated. It will doubtless be admitted by all, that there is a group of metalliferous minerals which have been the source of the metals in mining and which as a class may, therefore, be set aside as ores. Thus if I have in my hand an ounce fragment of specular hematite, I may properly say it is an ore of iron. It is a well-known and important member of the group of minerals which have furnished iron to commerce. But if I show you a supposed mining property with only an ounce of specular hematite in it, and in this connection refer to it as ore, you would laugh scornfully. We must, therefore, carefully discriminate in our minds the connection in which the word is used. To this technical use I will shortly pass, since it is the main point of interest, but I wish to clear away a few other preliminaries, relating to the use of the word ore in other senses.

In the microscopic study of rocks we have learned that minerals crystallize from a molten magma in a fairly definite succession and that the earliest group embraces magnetite, ilmenite, specular hematite, pyrrhotite, and one or two rarer metallic minerals, besides several non-metallics, such as apatite and titanite. We often call all these taken collectively as the group of the "ores," as contrasted with the ferromagnesian minerals; with the feldspars and feldspathoids; and with quartz. But we may set aside this use as not bearing in an important manner upon the question.

It is a time-honoured conception of an ore, that it should consist of a metal in composition with some non metallic substance, such as oxygen or sulphur, which disguises its metallic qualities and which is called a "mineralizer." Native metals are not ores according to this view. The copper of Lake Superior is therefore obtained from "copper-rock," not from ore. Gold is yielded by "gold-quartz," not by gold ore. But I think we must all feel that this old-time usage is no longer sharply observed and that it may well enough drop out. Thus in T. A. Rickard's interesting little book on "The Copper Mines of Lake Superior," we certainly find the output of the mines referred to as "ore."

Sometimes also in the mining of the non-metallic substance sulphur, the output of the mine is called "sulphur-ore," although no metal is involved at all. Yet while we may not especially controvert this usage, it cannot be said to seriously affect the general and large conception of ore as limited to the metalliferous minerals.

Finally, the word "ore" is used by Milton and other early English writers as meaning a metal itself, artificially produced; but of course this use is obsolete.

Let us now set in order the definitions which have been proposed and which treat of ore in its technical sense. We may then examine them somewhat critically and determine whether they satisfactorily formulate our present conceptions.

The most inclusive and sweeping of the definitions, which the writer has found, is one given by Dr. R. W. Raymond, in "A Glossary of Mining and Metallurgical Terms," in Vol. IX, p. 169, of the Transactions of the American Institute of Mining Engineers, 1881.

"Ore, 1. A natural mineral compound, of the elements of which one at least is a metal. The term is applied more loosely to all metalliferous rock, though it contain the metals in a free

state, and occasionally to the compounds of non-metallic substances, as sulphur ore. 2. Corn.* copper ore; tin ore being spoken of in Cornwall as *tin*."

Obviously the above definition is open to grave objection. Thus any mineral which contains a metal as one of its elements without regard to amount would be included. Hornblende with five per cent. iron would be an ore. Some other mineral with a half of one per cent. of iron or of manganese would equally come within its provisions. To be at all satisfactory we must delimit far more sharply and upon some other basis. Yet from the associations in which the definition appears, one would anticipate a technical rather than a purely scientific expression.

Wm. Humble, an English writer in a "Dictionary of Geology and Mineralogy, etc.," 3d. ed., 1860, gives the following:—

"Ore (erz. Germ.) A metallic compound. Metals are found usually combined with other substances; the compounds they thus form are called *ores* when the metal exists in them in sufficient quantities to form a considerable portion of the mass."

This definition introduces the idea of quantity, but not as yet in an altogether satisfactory way, the adjective "considerable" not being very definite. At what point do percentages pass from considerable to inconsiderable? Is not 20 per cent. of iron considerable, yet it would not warrant mining. Is 1-1200 of one per cent. considerable, and yet it might justify mining for gold. The word "metallic" being sharply used in mineralogy for a variety of luster, is also objectionable. We might question whether calamine, cerussite, siderite, and many other well-known ores would be included in the definition. Metalliferous is of course better.

Let us take now the two dictionaries which twenty years ago were chiefly cited in English-speaking North America. Worcester (1905 ed.) states. "Ore 1. A mineral body which is reduced to the metallic state by fire; a metal chemically combined with some mineralizing substance which completely disguises its usually recognized and useful properties."

The first sentence of the definition is very objectionable, since wet methods are no less serviceable than fire, in reducing the metals, and this delimitation for ore is obviously ill-chosen. The

*Corn., i.e., Cornish.

second sentence brings out the time-honoured conception earlier discussed. It is flatly contradicted by Webster whose definition will next be given.

"Ore 1. The native form of a metal whether free or uncombined as gold, copper, etc.; or combined as iron, lead, etc. Usually the ores contain the metals combined with oxygen, sulphur, arsenic, etc. (called mineralizers). 2. (Mining). A native metal or its compound with the rock in which it occurs, after it has been picked over to throw out what is worthless."

The first portion of this definition is so condensed in statement as to be literally meaningless.. Thus, as the word native is used in connection with metals, it distinctively means uncombined. How then could the native form of a metal be "combined as (presumably 'in the case of' to be supplied) iron, lead, etc?" We may infer that native means natural as opposed to artificial; but unless a reader knows more about the meaning of ore than good Noah Webster himself did, this definition will contribute little to clearness of thought. Curiously enough the second definition is scarcely better. Can a native metal be "compounded" with a rock? We usually employ in these senses compound to mean chemical union. Again, is the product of a mine never "ore," until it has been sorted over? Surely the majority of us would impose no such condition.

We come next to a series of definitions in which a distinction is made between the scientific use and the technical use and into which, for the latter, the condition of profit is introduced as a feature, although it is not always insisted on as essential. The late Professor J. D. Dana expresses his views as follows in his Manual of Mineralogy, 3d Ed. 1884, pp. 92–93.:—

"An ore in the mineralogical sense of the word is a mineral compound in which a metal is a prominent constituent. In the miners' use of the term, it is a mineral substance that yields by metallurgical treatment, a valuable metal, and especially when it profitably yields such a metal. In the former sense, galena, the common ore of lead, is, if it contains a little silver, an *argentiferous* lead ore; while in the latter, if there is silver enough to make its extraction profitable, it is a silver ore. Further than this, where a native metal, or other valuable metallic mineral, is distributed intimately through the gangue, the mineral and gangue

together are often called the ore of the metal it produces. "We have beyond to do with ores only in the mineralogical sense."

The Century Dictionary contains a definition, presumably by Professor J. D. Whitney, which is essentially the same:—

"Ore. 1. A metalliferous mineral or rock, especially one which is of sufficient value to be mined. A mixture of a native metal with rock or veinstone is not usually called *ore*, however, it being understood that in an ore proper the metal is in a mineralized condition—that is, exists in combination with some mineralizer, as sulphur or oxygen. The ore and veinstone together constitute the mass of the metalliferous deposit, vein or lode. The ore as mined is usually more or less mixed with veinstone and from this it is separated, as completely as may be convenient or possible, by dressing. It then usually goes to the smelter, who, by means of a more or less complicated series of operations, frees it from the worthless material, which still remains mechanically mixed with it, and also sets it free from its chemical combination with the substances by which it is mineralized."

The Standard Dictionary, whose definition presumably passed under the eye of either Professor W. H. Pettee or Professor N. S. Shaler, is shaped along the same lines, as follows:—

"Ore. A natural substance, sometimes forming part of a rock, containing one or more metals. The term is applied usually to a mineral from which the metal can be profitably extracted; but is sometimes extended also to non-metallic minerals, as sulphur ore."

In these three it is a little uncertain whether, when Dana and Whitney say with regard to profit, "especially," and when the Standard says, "usually," they mean in the technical as contrasted with the scientific use or not. No one of them absolutely prescribes this condition and a reader is somewhat uncertain whether it is essential or not. In definitions it is doubtless better to leave no ground for uncertainty or confusion of thought.

In Prime's translation of von Cotta's "Treatise on Ore Deposits," New York, 1870, p. 1., we find the following: "Under the general term *ores* are comprehended all minerals and mineral aggregates which, from their metallic contents, attract the attention of the miner. *Metalliferous deposits* are therefore for us, all local accumulations of minerals or mineral aggregates which correspond to this demand.

"The idea of the terms *ores* and *metalliferous deposits*, in mining parlance, cannot be well expressed in a more precise and scientific manner. There is not any particular class of minerals or of rocks corresponding to these terms. To them belong native metals, metallic oxides, metallic sulphides, and even metallic salts, and their combinations; but on the other hand not all metalliferous species of the Mineral Kingdom, because many of these cannot, either from their nature or the too small percentage of the metal they contain, proportionally to its worth, be worked with profit. No rock, for example, containing 5 per cent. of oxide of iron can be considered an ore; while on the other hand, a vein of quartz, with but 1 per cent. of gold would be regarded as a very rich and valuable metallic deposit, so relative is the idea.

"It is even possible, and has already occurred, that a mineral which for a long time was useless to the miner, and on this account was not considered an ore, has, by means of new discoveries, been included in the category of ores. Blende, for example, when it did not contain valuable metals, could hardly have been considered formerly as an ore, though commonly defined as such; but since a method has been discovered of extracting zinc from it with profit, it may be ranked without doubt among the ores."

The idea or condition of profit enters here, but it would appear that the authors intended to define an ore according to the condition that the metalliferous deposit should attract the attention of the miner; that is, it should be a deposit out of which at the outset the miner thinks he can make a profit, whether the result justifies his expectation or not. There is a possibility in this of which I will make further mention in conclusion.

We now come to a group of definitions which clearly treat of ore in the technical sense, and which base the meaning upon the possibility of profitable extraction or treatment. In Dr. Murray's New English Dictionary, 1905, the most comprehensive of its kind, we find:—

"*Ore.*—A native mineral containing a precious or useful metal in such quantity and in such chemical combination as to make its extraction profitable."

This definition is clear-cut and concise. We are reminded, however, that an ore is sometimes an aggregate of several minerals, any one of which perhaps if considered by itself would not be pro-

fitable, yet the sum total is. In the low grade copper ores of the Boundary district, the little gold and the little silver which are present are important factors in the total, yet no one of the three metals alone in these percentages could constitute an ore. It would have been well to have added after native mineral the expression "or aggregate of minerals" to allow for such cases.

In the "Universal Encyclopedia and Atlas" published by the Appletons in 1901, the following definition by Professor Thomas Egleston appears. It is taken from Johnson's Encyclopedia published twenty years earlier and of which the Universal is the continued revision.

"*Ore.*—A metal chemically combined or in the native state, mechanically mixed with other substances, which render treatment necessary to separate it. In a strictly technical sense, only those substances are ores, which contain the metal in sufficient quantity and of sufficient purity to make the treatment profitable. Arsenopyrite, a combination of arsenic, sulphur and iron, contains 34.4 per cent. of iron; but it is not an ore of iron because the metal made from it is not of sufficient commercial value to pay the expense of treating it."

In the same volume the expression "ore deposits" is defined by R. Pumpelly and Charles Kirchoff along the same lines, but a distinction is drawn between ore and gangue.

In other works of similar scope, like the New International Encyclopedia, recently published by Dodd, Mead & Co., very much the same definition appears: "Ore Deposits, the name applied to deposits or accumulations of metalliferous minerals or ores found in the earth's crust. The term ore includes those portions of the ore body in which the metallic minerals form a sufficiently large proportion to make their extraction profitable; aside from these, there are often quantities of associated non-metallic minerals forming masses containing little or no metal, which are termed the gangue."

Authors of books on mining are inclined to look with favor on the same line of attack. In the "Manual of Mining" by M. C. Ihlseng and E. B. Wilson, 4th Ed., New York, 1907, p. 3, after a paragraph treating of the native metals we find:

"*Ores.*—With these few exceptions (i.e., the native metals) the metals are found in chemical union with non-metallic sub-

stances, more or less completely segregated to constitute mineral. Any accumulation of mineral of good quality and in sufficient concentration to warrant the expenditure of energy for its extraction is an ore. Manifestly this is a fickle term since it depends for its stability upon the casual conditions of the market as well as upon the mineralogical features." In a glossary at the close of the work, there appears: "*Ore.*— A mineral of sufficient value (as to quality and quantity) which may be mined at a profit."

The short definition from the glossary is a little infelicitous in form, and a little sweeping in statement. It would, of course, include coal, asphalt, ozocerite, and other non-metallics, which the greater number of us would certainly hesitate to call "ores."

The longer statement introduces the term "mineral" which deserves a word of comment. Aside from its general meaning, under which are included substances of inorganic origin as against organic, the word mineral is used, in the United States at least, to designate in the large way the objects of mining, without special reference to profit or loss. Thus the law affecting the Public Lands recognizes "mineral claims," but either from a disinclination on the part of its framers to enter into the question of profit or loss; or else from a desire to embrace also possible non-metallic deposits, mineral is consistently used instead of ore. Thus C. H. Shamel states in his valuable treatise on "Mining, Mineralogical and Geological Law," New York, 1907, pp. 55–56:—

"We may summarize the American law as to the legal definition and meaning of the word 'mineral,' when used in deeds, leases or other legal instruments, as including in the absence of special provisions in such instruments, all metallic minerals of sufficient value to justify mining and extracting the same, whether for the purpose of reducing the metal therefrom or some other industrial use. It also includes rock used for building materials, etc., coal, petroleum and natural gas. Kaolin, brickclay, slate, etc., have not been passed upon by the American courts; but on the authority of the English cases, and the decisions of the land departments hereinafter mentioned, the probabilities preponderate that the courts will hold them to be included under the term 'mineral,' the same as granite, marble, etc."

In the paragraphs immediately following in the work cited, Dr. Shamel reviews the meaning of "ore" in the few cases in which

it has been defined by the courts. The definitions are in the purely scientific rather than in the technical sense. The courts apparently prefer "mineral" to "ore," wherever possible.

A definition very similar to the one from the glossary of Ihlseng and Wilson, is to be found on p. 598 of the "Coal and Metal Miners' Pocketbook," which is published by the International Correspondence Schools of Scranton:—

"*Ore.*—A mineral of sufficient value (as to quantity and quality) to be mined at a profit."

As remarked above this definition of course includes all manner of non-metallic minerals.

Several definitions from works on ore deposits will perhaps not be without interest. Thus in "A Treatise on Ore Deposits" by J. Arthur Phillips, 2d Ed., revised by Henry Louis, 1896, p. 1, we find:—

"Metals which occur in a state of approximate purity are said to be *native*, and when two or more such metals are found in combination the substance is called a native alloy. Usually the metals sought after by the miner are, however, not found in the native state but are mineralized by being united with various non-metallic bodies. In this way they combine with sulphur or chlorine, giving rise, respectively, to metallic sulphides or chlorides; with oxygen the metals form oxides, and with acids they yield salts, such as carbonates, sulphates, and phosphates.

"All natural combinations of a metal with such mineralizing substances are called ores when the proportion of metal which they contain, after suitable mechanical preparation, is sufficiently large to admit of their being advantageously treated by the metallurgist. Although perhaps not strictly correct, any material obtained by mining that contains a workable proportion of a metal is often called an ore, even if the whole of the metal be present in the native state."

"This definition perhaps unconsciously so far as its writer was concerned, contrasts the point of view of the metallurgist with that of the miner. But it is a contrast of which we shall need to take cognizance. Thus a miner might extract a quantity of metalliferous minerals from the ground at a loss. He might sell them to a metallurgist at such a price that the latter could profitably treat them. They might thus not be ore for the miner,

although ore for the metallurgist. If you saw a pile of magnetite at a blast furnace being successfully treated you would call it ore, even though it had been bought at the bankrupt sale of some miner.

In W. H. Weed's translation of Richard Beck's Lehre von den Erzlagerstaetten, under the title, "The Nature of Ore Deposits," New York, 1895, p. 1, we find the following:

"In a mineralogical sense an ore is a metalliferous mineral or a mixture of such minerals. Practically, however, this definition of an ore must be qualified by the statement that only those minerals and mixtures of minerals are ores *from which metals or metallic compounds may be produced on a commercial scale and at a profit.*

"Two examples of equal mineralogic or petrographic value may differ materially; a basalt carrying enough magnetite to influence the magnetic needle, but yet containing less than 10 per cent. of iron, is far from being an iron ore. On the contrary a vein with a silver content of only 0.5 per cent. is an ore deposit since with this content it is commercially valuable. In the case of a gold deposit the amount sufficient to distinguish a gold ore from barren rock may be even less, for in California and Dakota gold ores with only 4 to 6 grains per ton of gold are exploited. Hence it is the economic point of view that must always be borne in mind, the profit of working being subject to variation in the course of time. While nickel and cobalt were formerly nicknames for materials which were thrown upon mine dumps as useless, and were considered as a mere nuisance in silver mining, to-day, the compounds of these metals and the associated minerals are in great demand as ores.

"To a certain degree a mineralized material may be an ore in one locality and yet not be an ore in another place, the cost of reduction depending on the proximity to lines of traffic and cheap freights.

"The science of ore deposits is, in other words, the study and consideration of the deposition, distribution, and origin of rock bodies containing ores in such quantities that they may be extracted profitably by mining operations."

Heinrich Ries, in his "Economic Geology of the United States," New York, 1905, p. 223, gives the following:—

"*Definition.*—The term *ore deposits* is applied to concentrations of economically valuable metalliferous minerals found in the earth's crust, while under the term *ore* are included those portions of the ore body of which the metallic minerals form a sufficiently large proportion to make their extraction profitable. A metalliferous mineral or rock might therefore not be an ore at the present day, but become so at a later date, because improved methods of treatment or other conditions rendered the extraction of its metallic contents profitable."

R. H. Stretch in his handbook on "Prospecting, Locating and Valuing Mines, 4th Ed.," New York, 1903, p. 206, writes in this way:—

"An 'ore,' strictly speaking, is a single mineral which is a chemical compound of a useful metal and some other element or acid. In common usage, however, complex mixtures of pure minerals are considered as single ores; while free gold, native silver and native copper, together with their accompanying gangue minerals, are also classed as ore. Among miners, whatever will pay to treat or ship and sell is considered ore, as also low-grade mineral which might be utilized by concentration or improved facilities; but there is an indefinite shading off into material containing traces of ore minerals but hopelessly unavailable, and this is not considered ore; neither are gold gravel or platinum sands called ore. To avoid misunderstanding it is best to distinguish between the 'ore' (meaning thereby the whole bulk of the available product) and the 'ore mineral,' (usually very much smaller in quantity in all ores except those of iron, manganese, and some lead and zinc ores)."

Probably with search a few other definitions might be found, but without adding anything essentially new or important. I think that we must conclude that a distinction should be drawn between the purely scientific use of the word and the technical. Not every metalliferous mineral is an ore even in the former sense. Many can be cited which it would be ridiculous to call by this name. Nor can a metalliferous mineral be called an ore unless at some time it has proved to be a practicable source of some metal. Once successfully used it establishes its standing and joins the group of the ores. This differs from Professor Dana's definition that in an ore a metal should be a prominent constituent, since a species of

amphibole might have 5 or 10 per cent. of iron, iron being thus a prominent constituent, and yet not be an ore. I suggest the following:—

"In the scientific sense an ore is a metalliferous mineral belonging to the group of those which have profitably yielded the metals to the miner or metallurgist. In its technical sense an ore is a metalliferous mineral or an aggregate of metalliferous minerals, more or less mixed with gangue, and capable of being, from the standpoint of the miner, won at a profit; or from the standpoint of the metallurgist, treated at a profit."

The test of yielding the metal or metals at a profit seems to me in the last analysis to be the only feasible one to employ. In a new enterprise as we all know, it is customary to refer to the mineral in the ground as ore, before it is proved to be such by profitable operation. If the enterprise should subsequently prove unsuccessful, it would only remain for those engaged in it to say that they thought they had ore but that they had made a mistake. As soon as a shifting or variable standard is introduced, such as individual beliefs or expectations, such uncertain, changeable and on the whole unsatisfactory conditions are developed that a sharp definition upon a secure and unmistakable basis becomes an impossibility. On the other hand, the test of profit certainly meets the requirement that "Use is the Law of Language."

DISCUSSION.

Mr. Lindgren:—I have listened with very great interest to Prof. Kemp's remarks, wherein he points out how many different definitions you can get of a very common expression. I have had some experience of dictionary scientific definitions, and while I cannot recall the exact cases, in several instances the definitions, even those found in the most modern dictionaries, have proved hopelessly inadequate and even misleading.

In respect of the use of the word "ore", there are two examples I would like to add to those mentioned by Prof. Kemp. Out in Missouri in the lead and zinc regions, they speak of what we call crude ore taken out of the ground as "dirt", and they

use the designation "ore" for the concentrates which they produce. This custom led a very eminent German professor to make the statement that the zinc ores of Missouri carry 65 per cent. of zinc. (Laughter.)

Another instance of the use of the word "ore" is found in a publication of the Geological Survey of the United States, in which the author speaks of sapphire ore. It seems to me that it is questionable whether we need the term "ore" for scientific purposes at all. (Hear, Hear.) Why not restrict it simply to technical uses and why not follow Professor Ries' suggestion as to a definition. "A mineral aggregate which contains enough of metal to be profitably extracted", the word "profitably" to cover "actually profitable" or "intended to be profitable." We have then the case of the gold gravels which are not in the common usage included in this definition; it seems to me these really should be included even if it is impossible to change the usage. We cannot except the gold gravels from all other classes of ore, although we seldom really speak of them as "ore"; but then on the other hand I call your attention to the conglomerates of South Africa, which many eminent gentlemen consider gold bearing gravels, and which are undoubtedly spoken of as ore; then if you take the different conglomerates in South Dakota, —solid compact conglomerates carrying placer gold,—I think most of us would be apt to speak of it as an ore.

It seems to me it would be preferable to reserve the term "ore mineral," and Prof. Ries has already mentioned it in his book—to designate the different individual metalliferous minerals which occur in the ore, and I would suggest that we speak of ore in a technical sense as meaning a mineral aggregate which contains enough metal to be profitably extracted, and of "ore minerals" to designate the metalliferous components of that aggregate. (Applause.)

DR. LANE:—Of course it is difficult to control public usage of these matters. I have had a great struggle with the cement people who insist on calling bog lime, which contains 90 per cent. of calcium carbonate, marl, whereas you will find all the dictionaries define marl as a calcareous clay. Almost all our Michigan clays are calcareous clays, and are marl. But from the cement maker's point of view, they are not marls at all.

I think we ought to modify the definition that Professors Lindgren and Kemp have suggested, so that ore is that from which the miner may expect his profit. This, though, would probably exclude the placer gold, because the placer gold miner is not often referred to as really engaged in mining.

Mr. Lindgren.—I think most placer miners would take exception to that. They all like to be called miners. Some call them navigators or dredge people, but I think we ought not to deprive them of the name "miners."

Dr. Woodman:—Respecting the question of expectation of value, I have seen the definition put in this way by an eminent American engineer—that "an ore is a metalliferous substance, which stands some chance of being profitably extracted." This definition, you see, would leave the question a little elastic, allowing full play for such factors as cost of mining, treatment and transportation, and market value of the product.

Mr. Craig:—I have listened to Dr. Kemp's paper with a great deal of interest. In Ontario the question as to what constitutes a discovery is of very considerable moment. Since hearing the paper and the discussion I am hopeful that the elucidation of this point may be reached; but at the same time I would like to ask the Honorable Mr. Cochrane to say just what the Government means by a valuable discovery of mineral. (Applause)

Prof. Kemp:—May I add a word further. I have thought somewhat carefully over many of the points that have been advanced. I think it is a defensible point of view from which to define an ore as an aggregate of metalliferous minerals from which you might reasonably expect profit to the miner or the metallurgist as the case might be. We must qualify "expectations" with the word "reasonable", because if you merely make it a matter of expectation, you have the most variable of all standards. The promoter has a very different type of expectations from the investor. (Laughter.)

We have so many inflated enterprises that would involve us in all sorts of difficulties as regards any definition. Of course as soon as we introduce the idea of profit, it brings up various questions of casuistry. Suppose we have a remote camp where much mineral has been taken out and put on the dump. It cannot

be shipped to the smelter by rail nor carted away in waggons. After a while a railroad comes in and the mineral immediately changes to ore. It makes one feel as if there were an exceedingly variable and shifting standard in this case, but after all it strikes me as the most definite thing upon which we can base our final test. The profit of course ought to accrue to the people who invested their money to develop the mines—those who have borne the real burden. In speaking of the profits to the miner, I do not necessarily mean the man who pounds the drill. In all new countries I think we have the same experience. Unless I am mistaken Senator Stewart of Nevada, in one of the discussions about the western territories, in the United States Senate some years ago, stated that it took about seven dollars of the investor's money for every dollar of the precious metals that had come out of the far West. Whenever we visit the camps and see the innumerable prospect holes and take into consideration the vast amount of effort expended for the few prizes that have been won, it becomes clear that there is much reason in this statement; and so it seems to me that we might better speak of the material sought as "mineral," until it has gained its standing as an actual source of profit.

Sometimes we use the term "pay ore" as distinguished from other ore. Presumably this refers to the rich part of a vein that occurs along with the more barren part which we cannot separate in actual mining, but the entire aggregate may still be a source of profit.

It is perhaps not an easy thing to put into a few words exactly what we do mean, or what we ought to mean, but it is along either the line of a reasonable expectation of profit or else of an actually demonstrated profit that we are obliged to define this term. (Applause.)

THE RELATION OF MINING TO FORESTRY.

By B. E. Fernow, Dean of the Faculty of Forestry, University of Toronto.

(Annual Meeting, Montreal, March, 1909.)

In order to give to the discussion on the relation of the mining industry to forestry some local colour, rather than in the expectation of securing very valuabe data, the writer recently sent a circular letter to mine managers in various parts of the Dominion, in which questions were put to them in regard to the use and the conditions of local supply of mine timbers. Their replies have been utilized in arriving at some general conclusions.

A canvass of the mines of the United States, made by the writer twenty years ago, afforded information showing a minimum consumption of not less than 150,000,000 cubic feet—the annual growth of at least three to four million acres. In the coal fields of Pennsylvania, for which the best data were available, the consumption varied at from one-half cubic foot to one and a-half cubic feet of timber per ton of coal mined (bituminous). The iron mines of the Lake Superior field required over two cubic feet per ton; but the open pit mines were supposed to reduce the wood consumption for the total iron ore output to one cubic foot per ton.

In the precious metal and other mines the variation was found too extreme to afford data on which to base satisfactory conclusions. While the Bodie mine used 4.5 cubic feet per ton of ore; the Ontario could produce 100 tons with an average utilization of $6\frac{1}{4}$ cubic feet of timber. On the other hand, the timber consumption in such mines as those of the Comstock, the Montana and the Leadville mines, where large ore bodies are stoped and the Nevada system of timbering and cribbing is employed, is enormous. In 1887 the great Anaconda mine alone consumed over 1,000,000 cubic feet of mining and building timber, besides burning a large quantity of fuel-wood for smelting, this latter consumption in one camp alone amounting to 300,000 cords.

If it were assumed that the increased ore tonnage, during the last twenty years, was accompanied by a proportionate increase in wood consumption, the above figure would require to be increased to 500,000,000 cubic feet; roughly speaking, the annual growth of 10 million acres of well-kept forest.

We are not in a position to make even such approximations as these to the wood consumption by Canadian mines, for while most courteous replies were received from Canadian correspondents, they did not afford sufficient data upon which to issue a statement in any sense comprehensive. The impressions left by the perusal of the replies would, however, lead to the following generalizations:

1. Canadian mines apparently use very little timber, conditions of rock in most localities being favourable, and roofs requiring little support. Shafts and shutes, and structures above ground are responsible for the bulk of the consumption. Yet at some of the mines the consumption approaches that prevailing in the United States.

From the few reports available, the information points to a consumption of between one and eight cubic feet of wood per ton of ore mined. One of the Rossland mines indicates 1½ cubic feet; and at one of the Kaslo mines as much as eight cubic feet, which in these sections of the country can be purchased at a cost of about eight to twelve cents a cubic foot; while the Granby mines indicate a consumption of hardly one-third of a cubic foot. A very complete report sent in by the International Coal and Coke Company, of Alberta, indicates a consumption of two cubic feet per ton; the cost varying from two cents per lineal foot for dead, to eight cents for green timber, largely poplar and spruce, or say an average cost of five to six cents per cubic foot of timber cut on the Company's own limits. The consumption of the Nova Scotia Steel and Coal Company is also, probably, in the neighbourhood of two cubic feet at a cost of four cents per ton of ore. The Oldham gold mines use three cubic feet per ton, the cost of purchased material being from three to five cents per cubic foot for stulls and poles, and six to twelve cents for better class timber and lumber. The Dominion Coal Company, while using perhaps the largest absolute quantity of any Canadian enterprise in the neighbourhood, namely, of 1.5 million cubic feet, shows a very small per ton

consumption, hardly one-half a cubic foot, the pillar and stall working being mostly employed.

2. The life of timbers underground, which is, of course, variable according to water conditions and mine ventilation, seems, on the whole and as one would expect, longer than in the warmer climate of the United States. In the well drained workings of the Oldham mines the timbers are crushed by the heavy hanging long before their durability is tested; while, curiously enough, in lower, flooded workings the same class of timber supported the hanging; but the theory of the writer's informant, that the water contributed to their support, is scarcely tenable. Moreover, the increased moisture contents of the wood reduces its strength to its minimum, so that the probable explanation can be sought only in a different distribution of pressures in the lower levels. In the dry climate of the Rossland district, seven to ten years' life, at least in shafts, is not uncommon, with a reduction in the drifts to five and even three years. The Granby reports timbers put in when first opened nine years ago, still in good condition. In many districts, mines have hardly yet been worked for a sufficient length of time to afford data on this point. The kind of timber employed would also require to be considered in this connection.

At the International mine of the Dominion Coal Company, timbers have in some positions remained in good condition since 1869. In other parts their life has been less than two years, and they are mostly affected by rot in the first year, and that without distinction of species.

It is interesting to note that this Company is experimenting with a process of treating timbers to increase their life, but as yet without arriving at valid conclusions.

3. Throughout the eastern provinces the most satisfactory timber seems to be furnished by the spruce. The statement is made that it is found to carry greater loads and to stand heavier shocks than any of the other timbers found in the northern country. This would seem strange wherever the pines and hemlocks are in competition.

At the Dominion Coal Company's mines tamarack is given the preference, and next to it black spruce, which is supposed to have longer life; but lately the balsam fir is becoming the main supply. It is the least desirable species in point of strength and

life. This balsam, as the writer had reason to ascertain, forms fully 75 per cent. of the timber on the Cape Breton plateau, from which these mines are probably largely supplied. Another reason assigned by the reporter is that spruce on the mainland has been either largely cut out or brings a better price as pulpwood, and hence the mine is obliged to depend on the poorer material.

In eastern Ontario, the most satisfactory results underground are said to have been secured from the use of elm; except that its life is shorter than that of spruce. For lagging, cedar, which is the most lasting wood, is preferred if obtainable. In British Columbia the best timber is, of course, the red fir, while the larch is rather brittle, yet, in comparison with spruce and bull pine, superior.

4. The question of the continuity of supplies in the face of the relatively small supplies required, causes as yet little concern. Most of the Canadian mining enterprises are so young that local supplies have so far appeared ample, and prices low. Yet, it is significant to note that in some instances not only is the increase in prices due to increased haulage, commented on, and felt to be a burden, but the needs of the future are beginning to be considered. From the General Chemical Company, operating at Sulphide at a depth of now 400 feet on an ore body 22 foot width, the statement has been received that "mine timbering was an expense to which we could not afford to go." And the writer expresses the belief that with proper management, timbering might be almost entirely dispensed with, except for shafts and shutes.

This statement recalls a similar example from the Menominee range, once one of the best timbered sections of Michigan, where a systematic rock filling method proved itself 50 per cent. cheaper than the use of timbers. A similar system is, in part, employed by the Canadian Copper Company, which uses not only rejected rock, but low grade ore, "this ore filling forming an ore reserve, mined and ready to hoist at a moment's notice."

Again: "The Eustis Mining Company of Capelton, Quebec, has experienced great difficulty of late years in getting satisfactory mine timber, and it is quite evident that this difficulty will increase from year to year. There is practically no satisfactory mine timber to be had within a reasonable distance from us. The probability is that we shall have to alter the system of mining to conform to the new conditions."

In other correspondents the question seems also to have stirred up the contemplation of diminishing supplies in the future, which future is being shortened by the much greater demand for wood materials from other than the mining industry.

Some of the mining companies own or control their own limits; but even these more providential concerns have, perhaps, scarcely realized that further wisdom may be applied in the manner of utilizing these properties, in order to insure continuous supplies. In other words, that just as they apply system and technical skill in exploiting their mines, they should manage their wood properties; they should practice *forestry*.

The first intelligent class of manufacturers, which has realized that provision for continuity of supplies of raw material is absolutely necessary, are the paper manufacturers, who have begun to practice forestry on their limits. Thus the Laurentide Paper Company employs a forester with a staff of 42 men to manage their large holdings. The Riordan Paper Company has commenced this work with a staff of a forester and 12 assistants to prepare for a regular management. These facts should stimulate other timber land owners to emulation.

To most people the word forestry is a synonym for tree planting; or else, if they do not dismiss it from their mind as a fad, they conceive its purpose is to make mismanaged, culled woods again productive. What every timber land owner should realize is that forestry—intelligent planning—should begin when the first tree is cut, for by the mere manner of exploiting his property be may make or mar its future. Forestry in the timbered country means to so cut the timber as to secure a natural reproduction without the necessity of planting; the mere use of the axe securing this result. The forester is then a logger who besides harvesting the logs can direct the wood chopper to do his work so as to secure a desirable aftergrowth.

How this is done may not be stated briefly and in general terms, for each case requires its own diagnosis and prescription, but it requires more than is generally believed—more than merely cutting to a given diameter limit, or removing only the "mature" timber, to secure this reproduction.

To describe silvicultural methods would be beyond the scope of this paper, the object of which is merely to invite mining engin-

eers to a fuller realization of the fact, that wood supplies are an exhaustible but restorable resource, and that by proper management exhaustion can be prevented.

If the needs of their mines do not call as yet for provident measures to secure continued supplies, the writer would remind mine operators that besides being managers of properties, they are also citizens, who should take a general interest in the conditions of their country. Moreover, they are, by their occupation, placed in localities and positions where they can exercise —more than any other educated class—a wholesome and intelligent influence on the rest of the community.

While the mining industry has not directly consumed much of the timber wealth, it has indirectly been responsible for untold damage to forest growth. For a large part of the devastation by fire is chargeable against prospectors who burn over the ground to facilitate their work, and forest destruction, particularly in the Rocky Mountain regions, is largely attributable to this cause.

For this damage, atonement should be made by a special effort on the part of the more intelligent mine managers to assist in preventing further damage and to throw their influence into the balance to raise the standard of commercial morality to a proper realization of the enormity of the offence of the "fire-fiend."

THE PROBABLE EFFECT OF THE ACREAGE TAX ON MINING LANDS IN ONTARIO.

By G. R. Mickle, Toronto, Ontario.

(Annual Meeting, Montreal, March, 1909.)

In order to estimate the effect the acreage tax levied by the Supplementary Revenue Act, 1907, will have, it is necessary to understand not only this Act, but also the conditions under which mining lands have been patented or leased from time to time in Ontario. This Act imposes a tax of two cents per acre on all lands patented or leased for mining purposes, situated in territory having no municipal organization. The tax is a statutory one, no notice or tax bill is therefore required. A penalty of 10 per cent. attaches if the tax is not paid by the date specified (October 1st. each year) and after a certain time the lands in default with regard to taxes are forfeited after notice is published in the Ontario Gazette. The Act requires that a tax roll should be prepared showing all the lands taxable. This will be referred to frequently in the course of this paper.

A synopsis of the various Acts and regulations is given in Volume II, Report of Bureau of Mines. Previous to 1867, when Ontario was formed into a separate province, mining lands were disposed of under Orders in Council. It was intended originally to grant 5 square miles or 3,200 acres, but this was never carried out, and the first grant of land as mining land was in a location of 10 square miles or 6,400 acres, the block being 5 x 2 miles, five miles being laid out along the supposed course of the vein. In those days they must have had great veins. The first "location" granted in this way was the Cuthbertson (Bruce Mines) containing 6,458½ acres; the patent is dated at Quebec on 5th October, 1852. In the case of islands or areas broken by any natural obstacles, the location might exceed or be less than 6,400 acres, and accord-

ingly there appear on the tax roll to-day 22 locations containing in all 132,685 acres, the largest being 9,793 acres and the smallest 1,130. The land was sold at 80 cents per acre and payments spread over a number of years. Priority of discovery was a first requirement.

In 1853 the regulations were changed so that by securing a license to explore, good for two years and costing $100.00, the licensee might secure an area not exceeding 400 acres, which must afterwards be purchased at $1.50 per acre. Subsequently the license fee was abolished and the land went to the first applicant under working conditions. These conditions were afterwards eliminated. In 1864 the Gold Mining Act was passed (27 Vict. Chap. 9) by the Legislature of the United Provinces. This Act was occasioned by the gold excitement on the Chaudiere and other rivers in Quebec and provided for the setting aside of mining divisions wherein licensees might stake out claims of small area (less than one acre.) Under the regulations existing from 1853 to 1869 about 35,000 acres of land were granted in parcels of 400 acres or thereabouts which now appear on the tax roll. The area of these locations in organized territory has not been ascertained.

In 1869 the first really important mining Act was passed in Ontario (32 Vict. Chap. 34). The area of mining locations was fixed at 320, 160 or 80 acres. Regulations were also contained in this Act for the declaration of Mining Divisions as in the Act of 1864, the area being 200 feet square or about 1 acre. Neither discovery or work was required to hold mining lands acquired by purchase the Act simply stating "Crown lands supposed to contain mines or minerals may be sold as mining lands", or they might be worked as mining claims if in a declared mining division.

In 1891 the Public Lands Act (54 Vict. Chap. 7) was amended so that the mineral rights were declared reserved in grants of land for agricultural purposes, even if the reservation was not expressly mentioned.

The Mines Act 1892 (55 Vict. Chap. 9) is the next important one, no substantial change was made in the size of the locations except that they might be 320, 160, 80 or 40 acres. The system of leasing whereby a part of the rental money might be applied on purchase was made a feature of this Act. Working conditions were included ($4.00 per acre during 7 years). The provisions

regarding mining claims staked by licensees in mining divisions were retained, the area being from 5 to 20 acres according as one or more persons were involved.

By the Act of 1897 (60 Vict. Chap. 8) discovery was introduced and the amount of land one person might apply for in one year was restricted. Working conditions were maintained.

By the Mines Act of 1906 (6 Edward VII Chap. 11) the whole Province where any Crown lands were left was divided into mining divisions. (See section 79). The mining location therefore automatically disappeared and the mining claim is limited to a maximum of 40 acres. The time in which the purchase price may be paid is three years after application. By the Act of 1897 in the case of mining locations it was three months (Section 37).

It was stated above that only lands in territory with no municipal organization were taxable. In order to form a municipality it is necessary to have a certain minimum of population; thus the Act "respecting the establishment of Municipal Institutions in Territorial Districts" (Chap. 225, R.S.O.,1897, Vol. 2) provides that a surveyed township or unsurveyed territory not exceeding 20,000 acres in area and with a population of not less than 100 persons may be formed into a municipality on petition of not less than 30 persons to a district Judge, who is required to call a meeting. At this meeting not less than 30 freeholders or householders must be in favour of forming the municipality. It requires therefore a population of a stable character such as can only exist where there is steady occupation. Lumbering operations, for instance, except those in connection with manufacturing lumber, are not likely to produce the necessary conditions and there remain then practically only agriculture and mining. If the land is not suited for agriculture and mining is not actively pursued, no stable population can exist and no municipalities can be formed, and the land, therefore, remains on the tax roll. In general, therefore a large taxable acreage indicates a backward state of mining.

Coming now to the map, in which the judicial districts have been adopted in dividing up the Province, as these are more likely to remain unchanged for a time than the mining divisions, the acreage of taxable land is given in each.

In Rainy River district the maximum size of any location is 320 acres except in case of broken fronts. Nearly all this land was taken up during the gold excitement of 1896 and 1900. There are also a great many acres bought for iron lands.

Thunder Bay contains about half the total taxable area of the Province, and includes most of the large locations of 6400 acres mentioned before. The balance of these are in Algoma. As stated before, there are 22 of these immense locations on the tax roll containing in all 132,685 acres. Seven more than this were patented with 42,418 acres which are now within organized municipalities, making 175,103 acres granted in this lavish way. These seven large locations (6,400 acres) happened to be situated where there was agricultural land and it is due to this that there was sufficient population to form municipalities.

The same conditions hold true in Algoma to lesser extent. In this district there is also a large area of Indian lands which have been patented by the Dominion Government. As the form of patent does not convey the mineral rights expressly, and gold and silver are reserved in the Dominion Lands Act, it has been held that the Indian Lands are not taxable under the Supplementary Revenue Act.

In the Sudbury District more municipalities have been formed, many of the townships having sufficient stable population to organize municipalities, solely or mainly on account of the mining industry.

Nipissing, which includes the Temiskaming and Montreal River mining divisions, where there has been such a great mining activity for the last three or four years, shows a very small taxable area comparatively. This is due to several reasons. In the first place most of the mining land has been staked under the Act of 1906, according to which, after staking, a mining claim may be held for three years without patenting provided the working conditions are fulfilled, consequently these claims do not appear on the tax roll. Then a great deal of the land that was applied for previous to 1906 was under the regulations governing mining divisions in the Act of 1897. A claim therefore could not exceed 40 acres. Moreover the successful mining operations have attracted a population sufficient to form municipalities and consequently many of the claims patented would not be found on

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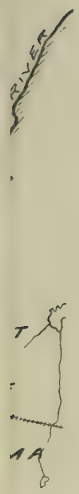

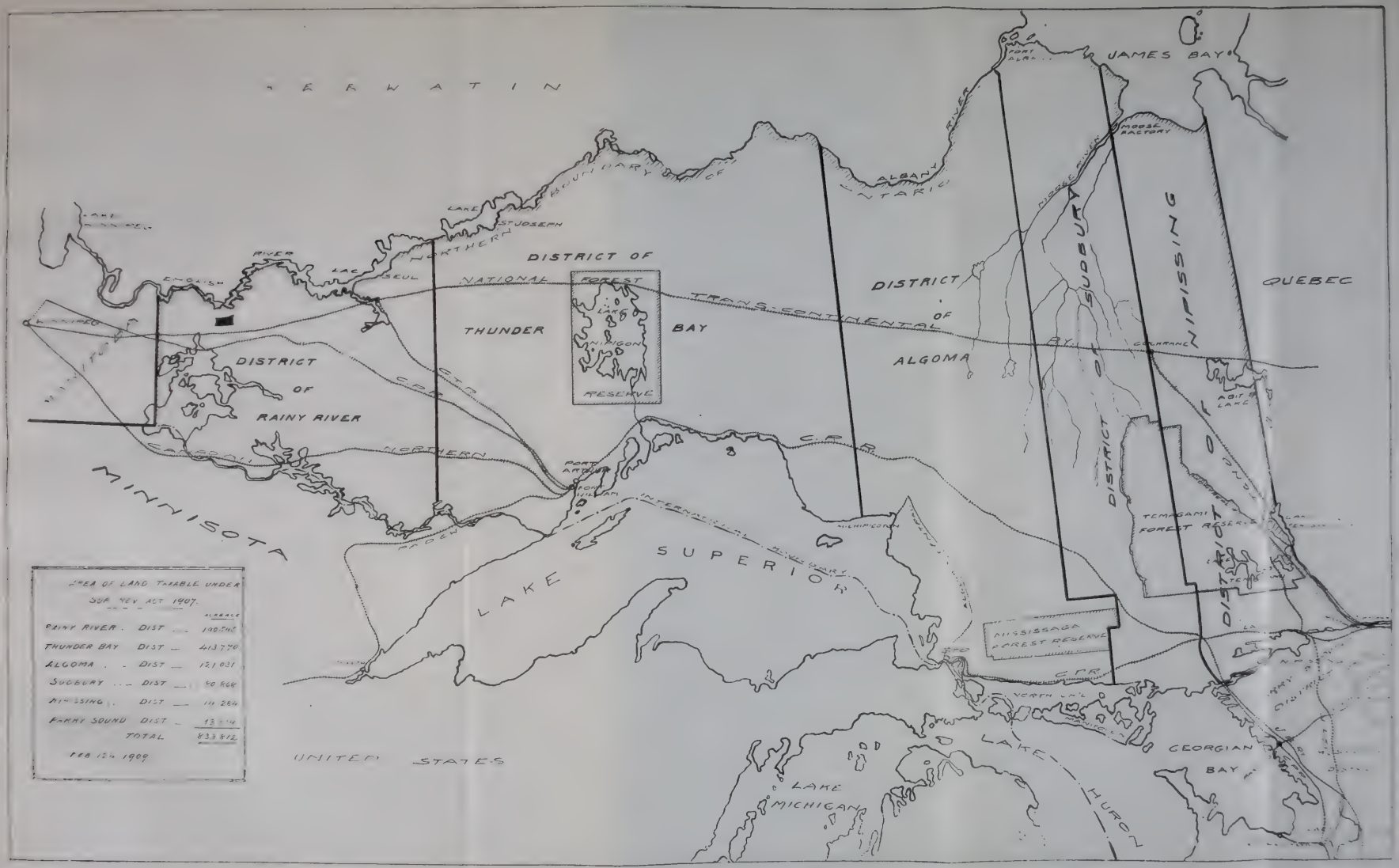

AREA OF LAND TAXABLE UNDER SUPPLEMENTARY REVENUE ACT 1907.

		ACREAGE
RAINY RIVER	DIST	190,740
THUNDER BAY	DIST	413,760
ALGOMA	DIST	121,031
SUDBURY	DIST	90,496
NIPISSING	DIST	111,264
PARRY SOUND	DIST	13,921
TOTAL		943,812

FEB 12th 1909

MAP OF NORTHERN ONTARIO, SHOWING AREA OF LANDS TAXABLE UNDER SUPPLEMENTARY REVENUE ACT, 1907.

the provincial tax roll. More municipalities will doubtless be organized, and even when a proportion of the great number of claims now existing are patented, there will probably be no very great area subject to provincial taxation for any length of time. The Larder Lake section, although something like 4,000 claims were staked there, shows very few patented ones although it is over two years since the heavy claim-staking took place there.

In Parry Sound, to which Muskoka is added, a great many acres have been bought as mining lands by lumbermen previous to 1897. This was done to secure sufficient land to pasture their stock. If applied for as agricultural lands, settlement duties would have been required and only a limited area (200 acres) would be granted.

The effect of this acreage tax cannot be fully determined till the time for forfeiture arrives. According to the Act the earliest date at which that can take place is the 30th June, 1910. At the present time a little over half the total area is in good standing with regard to taxes. Judging from the correspondence received and the way payments come in most of the owners intend to retain their mining lands. As a maximum I would consider 200,000 acres might be forfeited and a mininum of 100,000. In some cases the land belongs to insolvent estates; it is therefore not in the interest of any one in particular to keep up the taxes. In many instances also the owners acquired the land in time of an excitement and have lost all interest in it now.

DISCUSSION

The President:—Mr. E. L. Fraleck had proposed, I understand, to read a paper on this topic. He has, however, withdrawn it, but I will ask him to lead in this discussion.

Mr. E. L. Fraleck:—I am sure, Mr. President, that we are all very grateful to Professor Mickle for so clearly setting before us the actual operation and of forecasting the probable effect of this slight acreage tax, which has been operative for some consider-

able time in the unorganized part of Ontario. I do not think that any of us question the wisdom of levying this small tax of 2 cents an acre on the unorganized parts of Ontario; but it has always been an enigma to me, if we admit the advantage of such a tax on the unorganized part, why it would not be equally advantageous and beneficial to apply it in the organized part of Ontario. An anomally exists in the actual working out of this Act by which the producers in the Province of Ontario—those that are producing successfully—are taxed by a revenue tax on the output, and the holders of the land in the unorganized part of Ontario are taxed on the basis of acreage, and yet there are large tracts of land held in the province of Ontario, of which it is impossible to estimate the exact number of acres, but amounting to a very large area, that are held to-day absolutely free of any taxation or obligation whatsoever. I refer to those lands in the organized parts of Ontario where the mineral rights are held apart from the surface rights. These lands originally were taken up as mining lands. The surface rights were of some little value either for timber or agriculture or for grazing purposes, not required at all by the possessor of the mineral rights. The possessor of the mineral rights is only too glad to dispose of the surface rights of these properties, for certain reasons. In the first place they are of no use to him. He does not require them for agricultural or grazing purposes, and he is therefore only too glad to sell them to any one who will undertake the obligation of paying the municipal taxes year after year as imposed on agricultural land. In that way the possessor of the mineral rights evades any taxation whatsoever. The holder of the surface rights pays the municipal tax; the possessor of the mineral rights, of course, reserves the privilege of mining at any time, as against the owner of the surface rights.

Now, as long as the taxes are paid upon the surface rights, the holder of the mineral rights may vanish, and he has in fact in many cases vanished completely, leaving, in some cases, a mineral right of such value that it could be put into successful operation and become an asset to the people of the province as a whole, employing labour and producing wealth. There are many instances in the organized part of Ontario, and I venture to say that Professor Mickle has probably come across cases even in the unorganized part of Ontario, where lands were taken up by people

who were attracted to the country in time of mining excitement; those people have afterwards disappeared, and it has been impossible to get in touch with them. In the unorganized part of Ontario, these lands are coming back into the Crown Domain, and as Professor Mickle has pointed out, the earliest date of forfeiture is the 30th of June, 1910, when some 200,000 acres will be thrown open to the miner and prospector, and will constitute an asset to the Province.

Now, sir, if that small tax could be applied to the organized parts of Ontario, no doubt there is a great deal of land—probably thousands and thousands of acres that would come back into the Crown domain, which, together with those 200,000 acres in the unorganized part of Ontario, would be thrown open to the operations of the miner and prospector and no doubt much of it would become wealth producing.

Professor Mickle has pointed out that, in general, a large taxable acreage indicates a backward state of the mining industry; because where the industry is at all active and continuous, there will at once arise a population necessary to admit of the formation of a municipality. Therefore, I think we may take it for granted from Professor Mickle's statement, that practically all the lands which he has shown on this map are non-producing. If any of these lands were producing the conditions would at once arise for the formation of a municipality.

This leads us on a little further to the consideration of the advisability of increasing this tax somewhat. It seems to me an irresistible conclusion that this tax will effect a large measure of good to everyone interested in the mineral development of this country, and I think we should consider whether it would not be advisable to advocate that this tax be increased to five or ten, or even to twenty-five cents an acre. We see that it is not causing people to give up their holdings, but there is one thing it will do, it will impel the people who hold those lands to at once engage and send out prospectors upon their holdings; it will impel them to actively prospect their lands and select out of the total bulk of their holdings a very small acreage which will constitute the part they consider of greatest value and upon which a tax of even five or ten or twenty five cents would not be at all burdensome, and the remainder of the lands would at once go

back with the 100,000 or 200,000 acres into the public domain, and be thrown open to the miner and prospector.

Now, sir, I desire to make a statement that I cannot prove in its entirety, but I think I can prove it to a sufficient extent to carry weight with the meeting. I desire to say, there is not a country in the world to-day that makes any pretense of having a mining industry within its boundaries, outside of the Provinces of Ontario and Quebec, that does not impose an acreage tax on all the mineral lands within its borders, whether organized or unorganized. (Hear, hear.) The Province of British Columbia, practically every mining State in the American Union, and the Republic of Mexico have an acreage tax compared with which our two cent an acre tax is very insignificant.

If these countries, many of which are producing far more to-day than we,—if these countries find it advisable and even necessary in the development of their mining industries to impose an adequate acreage tax, then, sir, I do not see how our government can possibly justify itself in endeavouring to develop our mineral industry without such aids as these countries have found advisable to adopt.

I might call your attention on the map that Professor Mickle has handed us, to the Rainy River District, to the Thunder Bay District, and almost directly south to the great mineral producing States of Minnesota and Michigan. We all know that we have practically the same formation on our side of the line as is found on the south side; but what do we find? There are over 40,000,000 tons of iron ore going down Lake Superior and through the locks every year on the American side of the line, and not one pound on the Canadian side, except a few shipments from the Helen mine. The reason for that, sir, is because the mineral lands on the Canadian side are staked from end to end, and are being held for speculative purposes and no attempt whatever made to work them. The Steep Rock range further west is held the same way, and as we come east we find exactly the same conditions prevailing. The State of Minnesota and the State of Michigan, notwithstanding their great mineral production and the sound basis on which their mining industries are established, have found it advisable to have an acreage or a somewhat analogous tax, which is far more onerous than even a twenty five-cents an acre tax, which could be

adopted in the Province of Ontario. Increasing this tax and extending it to the unorganized part of Ontario is a measure which might cause a little inconvenience to a few individuals or corporations for the time being; but it is a measure that no matter what one's interest in the mining industry is, whether he be miner or prospector, mining engineer or promoter, speculator or broker —no matter what his interest in the industry is, I firmly believe that the adoption of this measure would be in the interest of every component part of the mineral industry of the Province of Ontario. (Hear, hear! and applause.)

COL. A. M. HAY:—I would like to ask Mr. Fraleck what the taxes are in Minnesota, because I was under the impression that there were none. I believe that the State reserves certain lands which they call School lands, and those lands are leased or sold with royalties attached, but I don't think there is a universal tax on mining lands in Minnesota.

MR. FRALECK:—I have a letter from the State Auditor of Minnesota. He writes:—

> "Dear Sir,—I have your recent letter requesting a copy "of the Minnesota tax law, and answering it, have to say "that I am unable to comply with your request for the reason "that the supply has been exhausted. Minerals in this "State are assessed the same as other lands, except that the "valuation is made to cover the mineral deposits. All these "lands are subject to assessment by municipalities, the same "as agricultural lands."

This, however, is a vastly different thing from a two cent an acre tax. That means that the assessor comes in on your property, takes your affidavit, and takes the various circumstances surrounding the holding of the property, and the value of the mineral lands in the section, and he assesses you on what he considers the actual value of your lands. Now, that is customary throughout several States in the Union. I would like to know if that would not bear a little more heavily than an acreage tax of just a few cents an acre.

*In the State of Colorado, by the Colorado Revenue Act (R.S. Sec. 5575) mining claims are required to be listed. The mines are divided into two classes, producing and non-producing. A gross output of $5,000 places the mine in the first class, and it

has to be assessed at one-fourth of its gross output. If the net output shows a profit of more than one-quarter, such net output is to be the valuation. Non-producing mines are to be assessed like other real estate at their supposed actual value.

Where surface and minerals are separately owned, they may be separately taxed, Cons. Coal Co. V. Baker, 26 N.E. 651. Stewart V. 23 S.W. 367.

A letter from the Registrar of the State of Colorado states,

> "Replying to your enquiry of the 12th, inst. would say that all land property held for mining purposes is subject to a state and county tax, the same as any other taxable property."

A letter from the Registrar of the State of Nevada states:

> "Amendment to Constitution State of Nevada provides for an acreage tax on Patented Mines. Tax to be on a fixed value of $10 per acre, other assessments covered by enclosed Nevada State Laws."

A letter from the Mine Inspector of Montana states:

> "All mining property is assessed at $5 per acre".

The General Tax Law of the State of Michigan, P. 43, Sec. 27 (3850) states

> "The words 'Cash Value' whenever used in this Act shall be held to be the usual selling price where the property to which the term is applied shall be at the time of assessment, being the price which could be obtained therefor at private sale, and not a forced or auction sale. In determining the value the Assessor shall also consider the advantages, and disadvantages, of location, quality of soil, quantity and value of standing timber, water power and privileges, mines, minerals, quarries or other valuable deposits, known to be available therein and their value."

Here in the organized districts where you have a mineral right, and a farmer or someone else holds the agricultural right, the municipality assesses the latter and the holder of the mineral right does not have to pay one cent in any way, shape or form or contribute one iota to any taxes within the municipality, including roads or bridges, or any other improvements. It has been contended by some that the forfeiture to the crown of these

one hundred thousand or two hundred thousand acres of which Professor Mickle informs us, would constitute an interference with vested rights, and would be an act of confiscation on the part of the Crown. This view is not held by the jurists of any country. In the State of Michigan they held that such does not constitute confiscation in any way whatsoever, but it does constitute abandonment by the owner.

The general Tax law of the State of Michigan, p. 149, Sec. 127 (3949), states:

> "Lands delinquent for taxes for any five years where said lands have been sold and bid off to the State for the taxes of one or more of the said years, and then so held, and no application having been made to pay, purchase, or redeem the said lands for said taxes, and no action pending to set aside such taxes, or to remove the cloud occasioned thereby, shall, within the meaning of this Act, be deemed abandoned land, unless such lands are actually occupied by the person having the record title thereto."

Everyone will, I fancy, agree that a mining property is of absolutely no value to its owner or to the people of the province, unless it be developed, rendered capable of production, and kept in operation, that is, mineral land lying idle and yet capable of production is of absolutely no value to anyone as long as it remains in that condition. The care of the people of this country should therefore be, that there will be more inducement to develop properties than to hold them idle. This will never be attained by penalizing success. One can even say that mineral lands are a public franchise, handed over by the people of this country to an individual or a Company, who shall have the profits of the business in return for the indirect benefit which will accrue to the people of the province as a whole through the operation of the mine. Viewed in that light, if a mining property is not made to produce, it should be placed in the hands of those who will work it to the advantage of themselves and the country. To effect this, however, no practicable scheme has ever yet been devised, and if it could, putting it into action, would cause too great a disturbance, and much temporary harm and injustice would be done. If, however, speculators, whether the company that holds its hundreds of thousands or the individual who holds his forty acres, desires to hold

idle what is in reality a public franchise, it is only fair to the people of this country that he should be under some obligation to them for the privilege of doing so, but it is also fair that the obligation should be just and equitable and not unreasonably oppressive or extortionate.

Where a mineral right is held by itself alone, the value of the minerals on the property, is evidently the only consideration actuating the owner, and if the owner desires to hold that land idle, he certainly should have no objection to paying the people of this country a small acreage tax when the public is spending a considerable amount of money each year in assisting him to render his mineral rights profitable. Surely any mineral right that is not worth such a slight obligation is not worth holding. The above measure would at once effectually clear up all imperfect titles, and again render available those properties which have been abandoned. It would in the future keep automatically clearing titles as time goes on. It would not take one cent from what the municipalities now obtain. It would work harm and injustice to no one, and would cause every owner to actively investigate the nature of the mineral rights he possesses. It would enable the prospector without large expense to know what lands are available for his operations and what are not. It would be a measure absolutely and entirely in the province of the Government to effect. It would be a relief eagerly welcomed by every miner and prospector in the older districts, and effectually prevent lands being locked up either by imperfect titles or speculative cupidity. It would raise a considerable revenue, and give a direct impetus to mining. It would dispel uneasiness in regard to revival of old claims which might be made against properties now in successful operation. It would be the cause of every element in the mining industry bearing its proportional tax.

It will be seen from the foregoing, that where the land is held in fee simple a tax is paid on the surface right to the municipality, where the mineral right alone is held, would be provided for by this measure. The only objection that has been made to passing such a measure, as above suggested, is interference with vested rights, and the term confiscation has been used as synonymous with that of forfeiture. That such a position is entirely untenable is clearly evident. The only properties that would be

forfeited, are those where the owners are no longer available, and those which the owners do not consider are worth the trouble of holding.

How can the term confiscation be applied to properties which have been abandoned in most instances many years ago? How can a man say his property is confiscated when he voluntarily hands it back to the people from whom it came, when it was clearly within his power and his own option to retain it? It cannot be said that the measure is directed against any particular class of either owners or holdings in the way of discrimination. It is rather merely equalizing a most unfair and unjust condition by which a certain class of owners and holdings entirely escape the obligations to which all others are subject.

It is in no way an arbitrary measure in the sense in which that term can be applied to the succession duty, which no one would have the face to characterise as unjust legislation. It is only practically a recognition of that principle which governs the regulations of the patent office and which leads to the cancellation of the leases in Algoma district, which everyone recognizes, is not only within the province of the Government to effect, but a wise and beneficial proceeding, which the Government should not neglect.

To the newer districts the measure will be one of prevention from future calamity; to the older districts, a relief from present intolerable conditions; to the mining interests of the whole province an aid, an impetus, the results which cannot help but advance its wealth and prosperity, and thereby contribute to the common good.

Mr. Coste:—Mr. President, I am delighted to see the manner in which this question is to-day being brought to the serious attention of this Institute and of the country at large. As you know yourself, sir, and as many of the members of the Institute know, this is a question that I have recommended in many ways to the Institute and to the country for a great many years past. My first report to the Geological Survey, twenty-five years ago, was on this very question, and I then suggested and advocated the principle of an acreage tax and I have ever since that time supported the imposition of such a tax, and I am very glad to see the progress that is being made in this direction.

I would like to ask Mr. Mickle if in the 833,000 acres or thereabouts of taxable mineral lands in unorganized territories, there is a single mine in operation?

PROF. MICKLE:—The Helen Mine is in an unorganized district and one other mine, the Creighton, and these are the only two instances of any really substantial mining operations being done in unorganized territory for any length of time.

MR. COSTE:—So that practically we have 823,000 acres of mineral lands idle and absolutely useless, and if we add to that what is held in the organized districts, the land that Mr. Fraleck has referred to and on which the owners pay absolutely no taxes whatever, I am sure that it will amount to at least one million acres of mineral lands held by companies that are mostly defunct, or by other people who hold those lands and do absolutely nothing on them. Now, I would point out that these lands are held where there were discoveries made as long ago as 1852,—the time the people first commenced to take them up. Wherever a discovery was made these lands were taken up, so that then our mining districts were first discovered—mining was coming into prominence —they were just coming to light, but immediately this principle of allowing these lands to remain untaxed was put into effect it simply killed the incipient industry. Every chance or possibility has thus remained unimproved and nearly a million acres in the Province of Ontario alone have been locked up; surely this is proof enough of the great necessity of an acreage tax on mining lands. I think the present tax of two cents an acre in unorganized districts is insufficient; it is a beginning however. But I entirely approve of Mr. Fraleck's suggestion that this tax should also apply to mining lands in the organized district. I believe a permanent committee of this Institute on mining legislation should be appointed by the Council to try and arrive at a basis on which to formulate mining laws, which could be recommended by the mining community of Canada to the legislature of the different provinces and to the Dominion, and I think a universal tax on mineral lands should be the fundamental principle of any such recommendations.

We must absolutely prevent this blanketting of millions of acres of mining lands in the Province of Ontario. (Applause.)

Unless we do so, development of the resources of the country will be necessarily retarded. (Applause.)

Mr. Johnston:—I would like to ask Mr. Fraleck how he would compensate the farmers for their lands?

Mr. Fraleck:—Well, if there was a farmer in Quebec for example, and we found valuable mineral on his place, we would not want to buy his farm. The main portion of his farm might be excellent for agricultural purposes and all we would want would be the surface rights of say three to five acres upon which to erect our buildings, right of way across his farm, and the privilege of mining. In many instances in Ontario, there are tillable fields up to the mouth of the pit, and therefore we would go to the farmer and instead of buying his farm in fee simple, we would purchase from him the mineral right.

As a matter of fact there are thousands of acres—it is impossible to arrive at the exact area without calculation—of farm lands where speculators have gone through and bought the mineral rights. Now, the farmer pays taxes on the surface to the municipality and there is no tax whatever levied on the mineral rights in the Province of Ontario—absolutely none. Frequently a man buys a mineral right, sometimes he does not even do that, he may only get an option, bond, lease or grant in writing and then disappears from the country, in which instances you have the title locked up for ever. I can point out place after place in eastern Ontario where it is absolutely impossible to get a title to the land on account of speculators who came there and put a cloud on the title fifty or sixty years ago, and in many instances the lands are now lying idle—lands in connection with which people interested in their development have spent thousands of dollars in trying to find a trace of those who bought the mineral rights.

Mr. Johnston:—But it would seem invidious to tax the man who bought the land and who owns the mining right as well.

Mr. Tyrrell:—Is there anything in the Ontario law that excludes municipalities from taxing mineral rights?

Prof. Mickle:—Yes, if separated from surface rights. The Municipal Assessment Act provides that mining land shall be

valued at the same price as agricultural land in the same vicinity. In the lower part of Ontario, where there are oil lands, the value of those oil lands is assessed at from twenty-five to one hundred dollars an acre, and in northern Ontario perhaps five to ten dollars an acre. That would mean a tax of seven to fifteen cents an acre at 15 mills on the dollar.

Then, the Supplementary Revenue Act provides that such area as is in actual *bona fide* use for agricultural purposes is not taxable unless the mineral rights are separated. If the mineral rights are separated from the surface rights then it becomes taxable.

THE PRESIDENT:—In Ontario the municipality can tax surface rights, but not the mineral rights when they are distinct. I think a little confusion has arisen concerning the regulations in the Province of Quebec. The Quebec Mining Law has been criticized in some respects, but I think Quebec is to be congratulated on the fact that they are keeping the agricultural rights distinct and separate from the mining rights, and I hope they will continue to do so. (Applause.)

DR. BARLOW:—A case may be cited of a property on which no taxes had been paid for years. Information was received by the Department that application was about to be made for this property, and the owners were instructed either to pay the arrears of taxes or abandon the land. They paid directly they heard that others desired possession of the property. In that case the Government notified the municipality.

MR. FRALECK:—Any confusion that has arisen in this regard, may be explained as follows:—The municipalities can tax certain land. They can tax it as agricultural land. If the land is mining land they can tax that mining land as if it were agricultural land. That is what has been done in the township of Coleman, where the land held by the mining companies is taxed as agricultural land. It is taxed as agricultural land and not as mineral land. I am satisfied that there is no case on record in the whole of Ontario. in an organized municipality, where the mining right was taxed when the land was held separate from the surface right. There are corporations to-day, in the Province of Ontario, that are holding as high as 400,000 acres of land, and they are holding those lands absolutely free from taxation. Probably I should not refer to

individual cases, but if I were to mention any case in particular it is not with a desire to see any corporation discriminated against, but simply by way of illustration. Take the case of the Canada Company which received considerably over one million acres of land in the Province of Ontario, in the year 1826. They have held that land ever since, and as the country opened up and as roads were built, and built at the expense of the people, and as railroads, bridges and schools were constructed, those lands began to rise in value. The timber was the first to have any considerable value and was sold separately. Then the surface right was sold to the settlers. Now, in eastern Ontario to-day the Canada Company still has approximately 400,000 acres of land, and in practically no instance do they hold the surface or agricultural right. They sold that land to the settlers years ago, and they reserved in their deeds all oil, gas, minerals and the right to mine, and all privileges of that nature. Now, there are mines in eastern Ontario to-day in operation that are operating under lease from the Canada Company and those mining companies pay absolutely no tax to any municipality on that mineral right, and the Canada Company pays absolutely no tax to this country on that mineral right—absolutely none. They simply sit down over there in England and draw their dividends.

Mr. Coste:—I would like to add a word to what Mr. Fraleck has just said, and it is this: I am very familiar with the Canada Company's land because I have often leased their lands for drilling purposes for oil and gas, and we have leases to-day from the Canada Company, and what happens is this:—The Canada Company has held these mineral rights on their original holdings for many many years, without paying any taxes whatever. But as soon as we go to them for a lease they demand an acreage tax from us, although they do not pay any such tax themselves. That is the first thing they demand. (Laughter.) Of course we are obliged to pay that tax, and it is sometimes as high as one dollar an acre and when it is not a dollar an acre, it is at least twenty five cents an acre. This company has thousands of acres at the present time; they held entire townships in the old days and they have retained the mineral rights in those townships to-day. Of course this condition of affairs retards the development of these mineral lands, not because the owners, whether the Canada Co. or other

owners force us to pay an acreage tax when we go to them for a lease, and to also pay them a royalty on the oil or gas produced—but because, as they pay no acreage tax whatever themselves, it renders them very independent and unless you agree to their terms, sometimes very exacting, the mineral rights under these lands remain untested and unproductive. Then again when we open up a field, the municipalities proceed to tax us on the machinery we have at the wells, on the pipe lines and pipes, and we have to pay this further tax to the municipality. Even when the owner of the oil and gas rights in our oil districts is not the Canada Co., but an ordinary farmer, he also demands from us an acreage tax of 25 cents per acre and we have to pay it. At the present time, one of our gas and oil companies is paying about $10,000.00 a year in acreage taxes alone to the farmers of that district from which it acquired the oil and gas rights. However, we are glad that we are paying that tax because it keeps other people from taking up neighbouring lands to those which we are using. These might be valuable and some day we may want them ourselves. (Laughter.) To my mind it is a great benefit to the operator, whether he is an oil operator or a mining operator, to have these taxes imposed, because at any moment he does not know what land he may wish to acquire, and if that tax leaves it free, he can take it and pay the tax and develop the property.

DR. BARLOW:—I think the Government should be congratulated on its policy with respect to imposing an acreage tax on these lands. At first the discovery clause prevented blanketting of vast areas; but now that this is practically abandoned, other measures must be taken to bring these lands back to the Crown domain, because some of it is very valuable. We all believe in the future of the north country, from a mining standpoint, and we would like to work for its legitimate development, so that we want to give these matters careful consideration. When, however, Mr. Fraleck speaks about a tax of ten, twenty, fifty cents or a dollar, an acre, I am not in concord with him, at least not at the present time. Surely when the Government puts a tax of two cents an acre on these unorganized lands, it must have given the matter some more serious consideration than we can at this meeting, because it is not a new idea. We must remember that we have a vast amount of unexplored ter-

ritory—territory that we all believe in. Now, we should not act too rashly in this matter; we should not, without due thought, advocate a tax that will be a hardship on pioneers. We are labouring under great disabilities at the present moment, but there is no reason why we should labour under greater disabilities. It is the prospectors and mining engineers who are developing this north country. It is not the government. Unless you produce a large amount of actual ore, they won't do anything, and I don't blame them. They want to see the considerable quantities of ore before they build expensive roads. They want to be sure that there is something in the country. The present lease system will not be taken advantage of in inaccessible territory for you have to wait too long for returns. It is the faith of the prospectors and mining engineers which leads to the opening up of new districts, but if at the start we have very serious handicaps in our unorganized territories, we cannot go ahead at all.

It seems to me at the present time that the two-cent tax which is proposed is quite sufficient. This, it is stated, will return a large acreage into the Government domain and in that way it will open up new territory that is now lying idle and cannot be prospected. I agree with Mr. Fraleck that we should extend it as far as possible to the organized districts, because in central Ontario I was brought face to face with that disability in certain mining locations that I examined, where we could not get any title to the lands—districts that are really valuable as mining locations and that are lying idle at the present time. Let us therefore go easy with this matter. It is a good idea and the Government have taken it up at the right time. Mr. Mickle says from one to two hundred thousand acres will revert to the Crown at a certain date. Well, let us be content with that for the present and don't let us hamper our mining industry in the north by imposing a heavy tax, because we have to do a lot of talking to get capital interested in that country, even with Gow Ganda ahead of us. (Laughter.)

I may perhaps here remark on the lack of uniformity in the mining laws and mining policies of the Dominion. It seems to me if these could be reconciled, it would be of inestimable benefit to the mining industry.

MR. BROCK:—I wish to express my opinion in favour of an acreage tax. So far as I have been able to observe, the greatest obstacle to the development of mining area is that of having the ground "tied up". (Hear, hear.) Every legitimate prospector or mining company wishes the ground to be open to location until it is wanted. I do not see what is to be gained by having the ground held by speculators. I have seen the development of a great many mining camps seriously handicapped on account of the ground being held by speculators or of title obscured. It seems to me that you should have a tax sufficiently onerous or it will not effect the purpose desired. In British Columbia there is a slight tax, but it is scarcely heavy enough, because we have districts in which a speculator has taken up a claim, which he leaves in the hands of an agent, who is supplied with a small sum of money sufficient to pay the taxes on that claim for a great number of years. Then the owner disappears, the agent has no idea of his whereabouts, and when a prospector or operator appears and wants to work that claim, he cannot obtain a right to go on it.

It seems to me that the principle ought to be applied to the organized districts as well as to the unorganized districts. In many parts of Ontario, and as I understand in Quebec, the mining rights were given away with the surface rights. It seems to me that that should not have been done, and if a tax is placed on the mining rights it will have the effect of causing the owners to abandon the mining right, and turn it back into the Government domain. (Applause.)

COL. HAY:—I would like to remark on a point which may have been overlooked in this discussion, that in view of the present condition in the north country speculators are encouraged to go there and are going by hundreds and thousands, assuming the rôle of prospectors. They are tying up claims and are staking everything in sight, and in this way the legitimate prospector is very seriously handicapped, because of this great crowd of men going in there and staking claims, not for mining purposes but for sale. The difficulty here is that the people who stake the lands as a rule have very little money—the prospector as a rule has very little money—and he may have to wait two or three years before he can sell his claim. I think, therefore, we ought to go slow about putting any burden on these lands that

will oblige him to sell his birthright. The conditions in Ontario are a great hardship on the prospector, and if you are going to handicap him further by an acreage tax, he will have to find capital to protect and develop his claims or lose them. It is all very well when the claims are in the hands of men who have money. That is an entirely different thing.

Prof. Mickle:—In regard to the question of taxing these mining lands in organized districts, of course the difficulty arises where the mineral rights are separated from the surface rights. That is a rather difficult problem to solve. The idea was that in the organized district, the municipalities would tax them and the tax would probably be a great deal higher. I am inclined to agree with what Dr. Barlow has said. From my experience I see there would be very great difficulty in frequently changing the Act, and I think it should be allowed to have a chance in order to see how it will work out. It is very difficult to get this information distributed amongst the different owners of mining lands who are scattered all over the country, and there are some correspondents of mine that I would be very sorry to meet if there are any more changes made in the law.

Mr. Campbell:—I have just returned from a three weeks' trip in northern Ontario—Gow Ganda and the adjoining territory—and I heartily agree with what the different speakers have said about this wholesale blanketting of lands. It is not fair to the legitimate prospector who explores ahead, as I did last summer, to select ground for future operations with the intention of making *bona fide* discoveries, and in that way acquire a title. I spent ten days on snowshoes up there, and I found the whole country was being blanketted. There were 631 claims recorded at Elk Lake, and I am satisfied there could not be more than thirty-one of *bona fide* discoveries at the outside. I would not myself undertake to make discoveries. I did not see a chance to do so in all the ground I covered. These people seem to consider that diabase is a sufficient discovery, and if they find diabase they think they have found something valuable, and I am convinced with respect to the majority of these claims, there is wholesale perjury going on. They swear to the discovery of galena, copper pyrites, gold and silver, and they cannot find it. I don't know what the Government is going to do about it, whether they will tax them or

not, but something will have to be done about it. There is no question in my mind that something will have to be done and done quickly.

MR. LANGFORD:—I have recently returned from India, and I think the mining law there has a distinct bearing on the question in Canada. There the mining laws in the majority of cases are quite distinct from the laws governing the surface rights. In India a man can obtain from the government a prospecting license over a certain area of land, which entitles him to work for one year only. During that year he has to perform certain conditions, and the most important of these conditions is that he must satisfy the government that an adequate amount of work has been done on his claim. If he satisfies the government that he has done the requisite amount of work on his claim, at the end of the year he applies for an extension of another year, and so on for three years. Then at the end of three years he either has to give up his prospecting license, or to take a mining lease over the land. I think if conditions of that sort were introduced here in Canada it would both help the small prospector and also help to develop the land. The man who first of all takes out a prospecting license pays only a nominal fee on the land taken out. At the same time he has his rights protected for a year, and having that right protected he can go on and do a certain amount of work. Whereas here in Canada, up in the northern regions, he does a certain amount of work knowing all the time that he cannot obtain a mining claim until he has made a discovery. He has to go on working, knowing that even if he does discover something which will give him a claim to the ground, before he can put in his claim another man may have found out about it and put in a claim ahead of him, and the work he has done is thrown away. On the other hand, in India, the prospector takes out a license over a certain area and he can go in and do a certain amount of prospecting work assured that for that year, for the nominal price of the prospecting license. his rights are absolutely protected.

MR. FRALECK:—It might be of interest to note that the tax in British Columbia, which Mr. Brock thinks too small to meet the conditions out there, is twenty-five cents an acre on patented claims.

In the Republic of Mexico the tax is 6 pesos per pertinencia, the area of which is equivalent to 2.74 acres. Six pesos is about three dollars, and that works out to something between fifty and sixty cents an acre. This tax has to be paid quarterly in advance, and if you do not pay the tax you are fined double what you owe the Government for the next quarter, and for the quarter after that you are fined three times. They multiply it three times by way of a fine, and if you do not pay it the land immediately reverts to the people, and is open for relocation.

Mr. Brock:—I might perhaps explain that when I said the tax in British Columbia was not large enough, I was expressing my own private opinion. Of course I don't own any land out there. I must admit that it is probable that the majority of people out there think that the tax is high enough, and it certainly has the effect of throwing open a large number of crown granted claims. For instance in Rossland, claims that were held ten years ago at a valuation of about three hundred thousand dollars, in a tax sale last year could be purchased at from one to three thousand dollars. The reason that I said I did not think the tax was high enough is that in certain camps prospecting has been stopped entirely by the crown granted claims, which were not worked at all. Very frequently you have a succession of mining booms following upon succession of discoveries. For instance at one period the prospectors will all be looking for silver, and perhaps one or two good claims are staked and then the parasites rush in and take all the land in the vicinity.

Mr. Macdonald:—Wild-cats!

Mr. Brock:—Not necessarily wild-cats. Sometimes they are very good claims. But they are sold to a speculator—a man who has money enough to pay to have the claim crown granted, and he holds it for speculative purposes. Now, if the silver lead does not turn out well in that district, and no important work is done, three or four years later gold may be found, and prospectors come in to prospect the ground; but when they find it is all staked out and crown granted, they leave the camp in disgust. The result is that the district as a whole is not prospected properly.

Major Leckie, Jr.:—While thoroughly agreeing with Mr. Fraleck's advocacy of an acreage tax on mineral lands, at the

same time I think careful consideration should be given to the matter of increasing the burden borne by the mining industry in general. Of course, if it would lead to a reduction of taxation on producing mines, this proposal would be doubly beneficial.

DR. BARLOW:—I think we are all of accord with regard to the imposition of this tax, but to my mind it is only a question of the amount. I think the sense of the meeting should be taken and communicated to the various governments so that there might be something done along this line, but the larger question of unifying the mining laws will also have to be considered. What we want is not only a uniform law, but a law which cannot be changed by Order-in-Council. I think it is just a question whether a committee should be appointed by the general meeting or whether it should be appointed by the Council.

THE PRESIDENT:—We have certainly had a very instructive discussion on the subject of an acreage tax. I am rather proud of the mining men for their unanimity in asking to be taxed. They are the only class of people that I have ever heard of who desire to be taxed.

MR. COSTE:—May I add a word to the remarks of Mr. Fraleck, referring to Mexico. He has said that the tax there on mining lands is from fifty to sixty cents an acre. The Republic of Mexico has improved its mining laws wonderfully of late years, and the best proof that the act works satisfactorily is that everyone there is pleased with it. There was a project on foot at the last session of their parliament in Mexico to entirely alter the mining law, but there was such a protest raised that the Government abandoned the attempt, and the law remains as it is, based on an acreage tax.

COL. HAY:—As the point has been raised, I think it very important that we should understand a little more of the working of the Mexican law. I understand when you denounce a pertinencia, you have to pay a certain amount per year. You have not got to go to the trouble and expense, as in Ontario, to find your land and stake your land, and comply with working conditions before you have any title. Immediately you pay a penny to the Mexican Government, you are protected. Now, if the law of Ontario were such that you could go to the Recorder's office

and say "Here is a piece of ground—does it belong to anybody"? If you are informed that it is open for location, you say, "Well, I will take it." You pay your money and it is yours for twelve months. That, it seems to me, would be a satisfactory law. Now, if the Mexican law is not hedged around with any frills such as the Ontario law, I would rather work under the Mexican law ten times over. (Hear, hear.)

SOME NOTES ON THE MINING LAWS OF ONTARIO.

By J. LORN MCDOUGALL, Haileybury.

(Cobalt Branch Meeting, December, 1908).

Senator Stewart, of California, has ascribed undeserved merit to the early miners in pronouncing them the authors of the local "rules and customs," that form the basis of the mining laws of America. In his letter to Senator Ramsey of Minnesota*, he says that the miners were forced, from the necessity of the case, to make laws for themselves; that each mining district formed its own rules and adopted its own customs, the similarity of which throughout the entire mining region, extending over an area of fifty thousand square miles, was so great as to attain all the beneficial results of well-digested general laws. They were democratic in their character, guarding against every form of monopoly, requiring continued work and occupation in good faith to constitute a valid possession.

This letter is an interesting document as coming from a representative miner, and is correct in stating the nature of the rules and customs and the uniformity of their adoption. But they were not the spontaneous creation of the miners of 1849-50. Historical accuracy requires that a different origin should be ascribed to them.

Mr. Gregory Yale, is more accurate when he says:

"The real mining code, as far as it can be traced by legal earmarks, has sprung from the customs and usages of the miners themselves, with rare applications of common-law principles by the courts to vary them. Most of the rules and customs constituting the code are easily recognized by those familiar with the Mexican Ordinances, the Continental Mining Codes, especially the Spanish, and with the regulations of the Stannary Convocations among the tin bounders of Devon and Cornwall in England,

*Appendix No. 1 to 3, Wallace's United States Supreme Court Reports.

and the High Peak regulations for the lead mines in the County of Derby. These regulations are founded in nature, and are based upon equitable principles, comprehensive and simple, have a common origin, are matured by practice, and provide for both surface and subterranean work, in alluvion or rock *in situ.*"

In the earlier days of placer digging in California, the large influx of miners from the western coast of Mexico and from South America necessarily dictated the system of work to Americans, who, with a few exceptions, (from the gold mines of North Carolina and Georgia, and from the lead mines of Illinois and Wisconsin,) were almost entirely inexperienced in this branch of mining. The old Californians had little or no experience in mining. The Cornish miners soon spread themselves through the State, and aided largely by their experience, practical sense and industrious habits, succeeded in introducing a systematised code. The Spanish American system which had grown up under the practical working of the mining ordinances of New Spain was the foundation of the rules and customs adopted. They reflect the matured wisdom of the practical miner of past ages, and have their foundation, as has been stated, in certain natural laws, easily applied to different situations, and were propagated in the California mines by those who had a practical and traditional knowledge of them in their various forms in the countries of their origin, and were adopted, and no doubt gradually improved and judiciously modified, by the Americans.

It is known, that the mining laws and customs of Spain prevailed in its gold and silver mines, long before the conquest of that country by Rome and continued without change after the Ancient Britons had taught the legions of Julius Caesar the mode of mining for tin. So that one sees that these laws and customs of Spain and Cornwall, which are the foundations of the laws of California, originated in remote antiquity, survived all change of conquest, language and race, and have been worked under by practical miners for hundreds of years.

The two main principles of these laws so adopted by the Californian miners were:

First:—That discovery is made the source of title:

Second:—That development, or working is made the condition of the continuance of that title.

Spreading from California, these two principles became universely recognized in the United States, as the basic principles of all mining laws, that were afterwards enacted there.

The British Columbian Legislature embodied them in its mining act. Ontario has made them so far as the written law goes, the foundation of its mining legislation.

The acquisition of title to mining lands in this way, by discovery, differs so much from the ordinary method of acquiring grants of valuable concessions from the government, that it is one of the most discussed and most interesting branches of law to consider.

In the Ontario Act, title legally begins with the discovery of valuable mineral in place. A discovery must take place in fact. It must be proved by an affidavit. The case of Attorney-General *vs.* Hargraves, decided the point that the Crown could have a patent set aside by showing that it had been obtained by a fraudulent affidavit of discovery. The law laid down in that case, is, in my opinion, still good law, and although I do not expect to see the Ontario Government again make attacks on titles as they did at the beginning of the Cobalt camp, there is nothing in the law that would prevent them so doing, if similar circumstances should arise again.

A little consideration would probably satisfy any person that the principle of discovery properly worked out, is the most satisfactory rule yet found for the development of the mining industry of a country, and for the proper protection of the prospectors in it. As has been pointed out, it is one of the oldest principles in mining law; it is a device suggested by miners themselves, and seems to be the best regulation to insure the keeping open of mineral lands for the prospector to work in, and obtain for him the result of his labour.

Notwithstanding the letter of the Ontario Law, under certain amendments, and practices followed by the department, it may be safely said, however, that the principle of discovery has been so reduced in its application that it may be said to have almost disappeared. It works out in this way: The Act allows an applicant to prove his discovery by an affidavit. On that affidavit to fyle an application. The applicant then is entitled to exclusive possession of the claim, and has the legal right to treat any other

person coming on the claim to prospect as a trespasser. If at the end of 60 (sixty) days, there is no dispute, or there has been no inspection by the government Inspector, or if inspected, the claim has not been thrown out, the applicant obtains a certificate of record. After which, no dispute is allowed to be entered. Thus by making a false affidavit, a person may obtain the right of exclusive possession to prospect for sixty days, and after that the right to the claim as against everybody, except the Crown. This is a right that is extremely valuable in a good district, but it puts a premium on false affidavits, and makes it practically impossible for the man who is particular about what he swears to, to obtain any claim in a good district, once the value of that district has been ascertained, for as soon as a valuable discovery is made, the surrounding country is immediately blanketed by the prospectors.

To prevent claims being obtained on these false affidavits, the law of 1906 provided for the inspection of discoveries by inspectors appointed by the department, and also provided that any licensee might enter a dispute against the validity of another's discovery. It was intended that in localities such as Coleman, where the value of the deposits were well known, that the government inspectors should work there continuously. There is no doubt that the inspection was the greatest help to the Township of Coleman. It centralized work there, and caused claims to be prospected in a manner that they would never have been had the prospectors not realized that they were subject to this inspection. The inspectors, however, in my opinion, were not numerous enough, and should have been empowered to report cases where, in their opinion, the applicant had shown complete disregard of the requirements of the Act, and had nothing on which to base a *bona fide* application, and should have been empowered in such cases, to prevent them restaking. This would have overcome the difficulty that repeatedly arose, of the man "thrown out" immediately restaking the claim and fighting any subsequent applicants who might make a valuable discovery for the lot or for an interest in it, and of usually obtaining in consequence some concession before he withdrew. Proper inspection would undoubtedly have entailed a certain amount of expense to the government, but in the interest of the mining industry it should have been carried out.

This blanketing under false affidavits might also have been prevented by the licensees themselves, if proper provision had been made in the Act for the determination of disputes under the Act. The Act gives the right of any licensee to dispute the discovery on a claim, but the practical value of this regulation is destroyed by there being no provision enabling the successful disputant to obtain any right to the claim.

For example: A has a claim staked in the winter, without any discovery. B goes on to the claim in the spring, and sees that there is no discovery, and enters a dispute on that ground and establishes that fact before the Recorder or Commissioner. All the Mining Commissioner has power to do under the Act, is to declare the claim open, the claim is then subject to restaking. A, B and the general public all have an equal chance.

The prospectors got over this difficulty for a while, by taking the risk of arrest for trespass, and prospecting on any claim on which they were satisfied there was no discovery, and on making a discovery, putting in a dispute, and at the same time fyling an application. Some of the recorders made a practice of turning such cases over to the Inspector, and if the Inspector reported that there was no discovery on the first application, and a discovery by the second applicant, deciding the dispute then and there in favour of the second applicant, who was granted the claim. This was a practical way of disposing of disputes, and until it was pointed out to the Recorder that the Act did not provide for this method of settling disputes, it was followed and worked fairly satisfactorily.

To add to the confusion in regard to disputes, the Divisional Court decided in the Cashman case that no appeal could be taken to them by any licensee who had entered a dispute unless the licensee had a valuable discovery, and another Divisional Court raised the question whether there was any provision for fyling a second application, or an application with the dispute. Fortunately, the case turned on another point, and this point was left undecided, but it shows the necessity of some clear cut provision being introduced into the Act which would enable the rights to a claim to be fought out without any hindrance, and the claim given to the winner of the litigation.

I might add, that to make matters still worse, the Cashman decision was considered by the Mining Recorders as binding on them and they consequently decided that a man was liable to a fine of $10.00 a day if he prospected on a lot which was recorded; and if he fyled a dispute and application, they could not hear the dispute if he had not a *bona fide* discovery. In one case in particular, the Mining Recorder followed the Cashman case and decided that he could not allow the dispute on the ground that the disputant had not properly staked the claim and that, therefore, he could not hear evidence as to whether the first applicant had a valuable discovery. This case was appealed to the Commissioner who decided that the Recorder was mistaken in the construction he had put on the Cashman decision, and that the Cashman case did not apply to the Recorder, but after the Recorder had applied it, although mistakenly he could not give any relief because the case came to him by way of appeal, and the Cashman case was binding on him. A thorough revision of the provisions regarding disputes should be made, so that matters can be tried out on their merits.

So far as known, we have not yet had any judicial opinion on some very nice points that will undoubtedly arise. For example: An application is made on a vein showing copper pyrite. Subsequent workings show that the vein carries silver values, at depth. Is the discovery of copper pyrite good or will the law hold that you must show enough copper pyrites to make it valuable to work as a mine of that mineral? Another question has arisen that is of some interest. That is, the Divisional Court has decided that if a man stakes on a vein carrying no values whatever, that he can claim as his discovery another distinct vein twenty feet away, which happens to show values. There is, however, a dissenting judgment in this decision, and appeal has been taken. Nevertheless at the present time it stands as law.*

There are many other points in our law which have arisen, and which are of some practical interest, but they are not different from the laws in other countries. We have the same difficulty about the enforcement of prospecting agreements and of partnership agreements.

*The Court of Appeal have since reversed this decision.

Our law is also unsatisfactory in its procedure for the trial of complaints generally. The Act of 1907 we were to follow the the High Court practice as nearly as possible. In the amendments of this year, it is provided that the Commissioner shall direct the procedure. As the Commissioner lives in St. Thomas, except when Court is sitting, it adds additional cost, unless we are prepared to simply go into the case without any previous notice of what the opposite side may set up. We should have some established procedure.

The Act of 1905 was the first act to provide for a Mining Commissioner who would try disputes at or near the locality in question, and the appointment of the present Mining Commissioner and his performance of his judicial duties has been most satisfactory and most helpful to the proper administration of the mining laws, and to him we are indebted for many of the most practical suggestions that have been embodied in the recent amendments.

In conclusion, it is a matter for remark that Legislative bodies apparently experience difficulty in comprehending the conditions with which they require to deal in framing laws relating to mines and mining, nor do they seem to appreciate the immense advantage it is to a country to have a vigorous body of prospectors and miners at work, engaged in developing what would otherwise be a wilderness. This lack of appreciation of the true value of mining has been shown before. In the California boom, when Senator Stewart was endeavouring to bring about the passage of a suitable mining act by Congress, the United States Congress manifested the strongest feelings in favour of the opinion that the mines of California should be taxed sufficiently to pay the national debt of the United States. Although this seems ridiculous at the present time, "*especially to those living in New Ontario*," yet it is a fact that some people believe that although a man may have risked his money and time to discover and prove the value of property, the existence of which was previously not known; that although this discovery may and does make an addition to the real wealth of the country; nevertheless the discoverer should be required to give a quarter or a half of his property to the government as a contribution to the needs of the rest of the public, who have taken no risk in the matter whatsoever.

Or, as a well known author says:

"Compelling other people to liquidate your obligations, has been in all ages and in all nations a highly comfortable and popular proceeding."

DISCUSSION.

Dr. Barlow:—In expressing appreciation of the several points raised by Mr. McDougall, I may, perhaps, remark that some little time ago I entertained the belief that I had a more or less thorough grasp of the provisions of the Ontario Mining Act. I must now confess, however, that I find I flattered myself unduly in this respect. Discussing some of the features of the Act, I, personally, am not in favour of the "discovery" clause. The operation of this clause has, in many instances, resulted in great hardship to prospectors. The object of the provision to prevent blanketing was, of course, excellent; but possibly a better system would be to limit the number of claims any one man could hold, to limit the number of licences, and prohibit the staking of claims in the names of others. The prospector, moreover, should be compelled, after staking a claim, to proceed at once to develop it. An instance of hardship in respect of the operation of the discovery clause may be cited in the case of the Bloom Lake district. Here the men first in the field were deprived of their claims by the Inspectors, on the grounds that the discoveries were inadequate; and very shortly after the claims were restaked by others who came into the district later, and succeeded in establishing titles.

A second provision in the Act, namely, the "working permit," also constitutes a serious defect. No sensible man will now apply for such a permit, for by so doing he publicly advertises that the territory he wishes to investigate is promising, and thus invites others to make discovery there in competition with himself. The Department of Mines should provide for the establishment of private offices in connection with the Recorder's office, where prospectors, desiring to confer confidentially with the official,

might do so without fear of others overhearing what was said. Thus, under the present arrangements, information that may have cost the man much time, trouble and hard work to obtain, speedily becomes public property; a rush follows to the locality, claims are frequently restaked, and the original discoverer may even be dispossessed of his find.

The present Act, furthermore, is so framed as to actually invite disputes and litigation. Directly a man has staked a promising claim, he must expect to have his title disputed by others who hope to either be bought off, or receive an interest, relying on the knowledge that the original discoverer will likely prefer such a settlement to the expense of litigation. The provisions of the Act, in fact, have become so complicated that their interpretation by even an intelligent educated man is next to impossible. Under such circumstances how can it be expected that the ordinary prospector will avoid falling into error? It is greatly to be hoped that the law will be simplified.

MR. DAVIS:—In the Montreal River district and, in fact, in mining districts throughout the province the "working permit" has been taken advantage of to "blanket" claims on which the possibility of discovery is doubtful. The sixty day clause has, as Dr. Barlow remarks, prevented legitimate prospectors from using the working permit. I think the attention of the department should be called to the lack of system, and demoralized conditions of the Recorder's offices regarding the official recorder's maps. These maps are practically made by the prospectors themselves, who indicate to the Recorder the position and boundaries of their claims. It is often many months before these locations are inspected. The remedy is simple. The employment of a much larger force of inspectors is imperative if confusion and litigation is to be avoided.

I agree with Dr. Barlow that the discovery clause has failed to fit the conditions existing in the new fields. I do not think it practical to limit, as he suggests, the number of claims that any one man can hold. But I do believe that a licencee should be allowed to hold his claim regardless of "discovery" so long as he complies with the working conditions.

I suggest that these conditions be made more stringent and that no patent be granted until a *bona fide* discovery of valuable

mineral in place be made, inspected, and passed. This would result in more development work on promising claims and less staking of unpromising ones for "wild-cat" purposes.

Dr. Barlow:—The question of the exact situation of claims has become a very serious one. The map of the Bloom Lake district, for example, is most misleading and erroneous. Thus, the Recorder has recorded certain claims which are described as being to the south of a locality, whereas to my knowledge these claims are situated well to the north of the locality in question.

Mr. Mickle:—In the main I agree with Mr. McDougall's contentions, but some of his statements are certainly open to question. Thus, he states that the insistence of "discovery" before title is granted, is a new departure differing in principle from the basis on which title is granted by Government to public lands other than mining. In my opinion the basic principle is the same in all cases. This principle is that property must be improved or increased in value before title is granted. In the case of agricultural lands, it is a simple matter to specify exactly the nature of the improvements to be undertaken; but in the case of mining lands, this is not possible. You may riddle a mining claim with shafts, but unless you find and develop an ore body, your work is of no value, and you have added nothing to the value of the property. The only way, therefore, by which mining lands can be improved is by discovering mineral of value on them.

Reference has also been made to the "working permit," which has been condemned. The "working permit" was intended to cover cases where it was difficult to make surface discoveries. In Cobalt district, for example, the territory east of the O'Brien mine is covered with drift from thirty to forty feet deep, and on my advice many prospectors took out "working permits" to prospect in this territory.

Mr. Davis has criticised the district maps; but I do not believe any better map has been issued than that provided to prospectors as early as 1905, when the great rush started to the Cobalt district. In this map the geology was most accurately shown. The maps of the Montreal River district have been equally good.

MR. DAVIS:—I referred only to the official map in the recorder's office, from which the prospector obtains the only available information regarding vacant territory. I quite agree with Prof. Mickle that the information supplied to prospectors by the Department has been, with this exception, remarkably complete and accurate.

DR. BARLOW:—In the Bloom Lake district in particular it is extremely difficult, if not impossible, to learn from the official maps whether or not areas are open for location.

MR. MCDOUGALL:—Mr. Davis has urged that work be done continuously on a claim prior to discovery or for the purpose of discovery. This is a suggestion worthy of attention and if acted upon would perhaps overcome some of the objections which have been raised against inspection. It is generally conceded that the conditions of affairs at the present time are not satisfactory. The law as to discovery is absolutely dead and nobody attempts to observe it, but it nevertheless certainly has some good points. The working permit which was referred to by Prof. Mickle is the alternative, but in the practical, working out, the 60 days' delay in granting the application, as Dr. Barlow points out, allows time for others to apply for the property. In my own experience it has taken from the first of May, 1907, to secure a working permit on one piece of property in Coleman, and the matter is not yet finally settled. But if a man could obtain a working permit a day or so after he had staked a property, one difficulty would be removed. He could take possession of his claim and as long as he was working there he could not be disturbed. That was the law in the old placer diggings in California. If a man abandoned work for twenty-four hours he lost the claim, and another could take possession of it; but while he worked continuously the claim was his. We should, I think, stick to the principle of discovery but protect the man working under that principle.

MR. FRALECK:—It would be very unfortunate if the meeting closed to-night with a misapprehension. We have been told by Mr. Davis and Dr. Barlow that they are opposed for inspection for discovery. The Act as applied in the township of Coleman in the summer of 1906 gave very good satisfaction and made the Cobalt camp what it is to-day. Many things complained to

have been added to the Act since that time. The working permit was the first compromise with the "smoking-room" prospectors, and every change since that time has weakened the Act and has retarded development without any corresponding benefit. The old incentive to make discoveries has practically vanished. This is proven by comparative stagnation in the business of the assay offices which formerly had difficulty in handling the amount of work brought in from the field by prospectors.

NOTES ON THE OCCURRENCE OF THE ORE BODY AT THE CITY OF COBALT MINE.

By FRANK D. ADAMS, D.Sc., F.R.S., McGill University, Montreal.

(Annual Meeting, Montreal, 1909).

A specimen* recently obtained from the City of Cobalt Mine, Cobalt, Ontario, for the geological collection of McGill University, presents certain characters which make it sufficiently interesting to become the subject of a brief note. The specimen in question measures 10 x 10 x 8½ inches, and consists of a block of the country rock of the City of Cobalt Mine, traversed by three parallel veins, from one of which an off-set crosses to the adjacent vein. These veins average 1½, 1¼ and ½ inches in width respectively and are filled with smaltite and calcite, together with a certain amount of native silver.

An inspection of the broken surface of the block shows no other features of especial interest, but on sawing the specimen across and polishing it, a rather interesting feature was brought out in addition.

The country or wall rock, which makes up the bulk of the specimen, is the Huronian breccia conglomerate, in which, however, the pebbles are few and scattered, the matrix forming the greater part of the rock; this matrix on the polished surface is normally dark green, almost black, in colour, but each vein presents a zone or border on either side varying from a quarter to three-quarters of an inch in width, which is, on the whole, lighter in colour than the normal rock and has a more or less distinctly fibrous appearance, the fibres standing at right angles to the walls of the vein.

When thin sections of the rock are examined under the microscope it is seen to be composed of an extremely fine-grained

* The large specimen from the City of Cobalt mine, to which reference is made in this note, was exhibited at the meeting.

mosaic, showing in the angular outlines of the larger grains its distinctly clastic character.

When, on the other hand, sections of the darker wall rock immediately bordering the veins is examined under the microscope there is seen growing in this mosaic especially, long minute fissures, standing at right angles to the course of the vein, in regular shaped strings of calcite. These are composed frequently of large individuals many times greater in area than the individual constituents of the rock itself. While following these minute fissures the strings of calcite often widen out into irregular shaped spots and masses.

This calcite is, in some few cases where the impregnation is very intense, accompanied by a certain amount of ore, recognized by its metallic lustre and reflected light. The calcite and the ore occurring in this manner, while starting to develop along minute cracks, for the most part replace the substance of the original wall rock itself.

Certain ore bodies have been developed by the filling of fissures in a country rock. These are "true fissure veins." The term "fissure veins," however, has been rather loosely employed. In the case of some deposits the solutions passing through the fissure and depositing in it the material of the veins, do not in any way attack the walls. In such cases we have the old-fashioned type of "true fissure vein"—a true fissure filled up and bounded by absolutely sharp and unaltered walls of the country rock.

In other cases, however, the solutions have not only filled the fissure but have attacked and eaten into the wall rock ; in some of these cases this action is more pronounced and so vigorous that the original walls of the fissure have entirely disappeared and the veins, while holding to a definite strike, fade away imperceptibly into the country rock on either side. The vein thus passes into that type of ore body known as an impregnated strip.

While the cobalt veins approach very closely to the first type mentioned, a careful examination of the specimen under consideration shows that in the case of the City of Cobalt veins the wall rock has not remained quite intact, but has been attacked to a certain extent by the solutions or solvents which filled the fissures and have been to a certain extent impregnated by the vein material. The material which has been deposited in the wall rock is

chiefly the carbonate gangue stone of the vein, but in certain places where the alteration is more intense there has also been a certain deposition of ore in the zone of altered rock bordering the vein.

DISCUSSION.

MR. HOPPER.—I would like to ask Dr. Adams whether the wall rocks at Cobalt are softer than usual, to allow of penetration beyond what is generally the case in such deposits, and if that would account for the solution penetrating through the wall rocks and beyond, or if he has any other reason to assign for it.

DR. ADAMS.—Of course the penetration of the solution into the wall rock depends, in the first place, on the character of the solution itself; that is to say, the chemical composition of the dissolved materials; and, in the second place, also on the porosity of the wall rock. In this case I should say the wall rock was of medium porosity, and one which was easily attacked.

MR. COLE:—In this connection it may be of interest to remark that in a recent lawsuit at Cobalt the point of contention was that a certain mining company had overrun their limits, and it became a matter for engineers to determine the value of the ore that had been removed from a certain length of drift. The method adopted to determine this point was the ordinary one of first sampling across the vein. It was found that as the length of the drift was comparatively short, and the ore very variable, the plan of taking ordinary chip samples across the vein at every so many feet, was not dependable. Hence a section representing the entire length of the drift was taken out and divided into four foot sections, and a layer of the whole vein removed as uniformly as possible, and from that samples were taken, the value of the ore both on the bank of the drift and on the floor being by this means determined. This was satisfactory in so far as it applied to the valuation of the vein matter; but it was also stated that the wall rock mined and placed on the waste dumps was of considerable value. In fact, representations have been made that

this rock from the different mines of the camp varies in value from ten to five hundred ounces; but this is scarcely correct. The method adopted, however, in determining the value of the wall rocks in this particular case was by making a cut at right angles to the vein on either side, at distances apart of two feet, and taking chip samples therefrom. These were assayed. As the distance from the vein increased, samples were taken at every twenty feet, but in the total length of 125 feet of this little drift it was found that none of the samples on the second foot away from the vein assayed over two ounces. In most cases the values showed only a trace, and consequently only samples taken of the wall rock for a width of a foot from the vein were taken into consideration for valuing purposes. But even within this limit, values were often very low, and the actual results were much less than anticipated.

In examining other veins in the camp, some have proved to be very rich, and others absolutely barren, but as a general rule the values contained in the wall rocks have been very much less than supposed.

THE ELECTRIC FURNACE AND THE ELECTRO METALLURGY OF IRON AND STEEL.*

By A. STANSFIELD, D.Sc., McGill University, Montreal.

The lecturer first gave a short account of different electrical heating appliances such as the resistance furnace, typified by the carbon filament electric light, and the arc furnace, typified by the common arc lamp. Small furnaces of these and other types were shown in operation and used for melting metals. One of these furnaces was provided with a lens and mirror by means of which a brilliant magnified picture of the interior of the furnace was projected on to a screen, showing in its natural colours the appearance of the metal as it melted down in the intense heat of the electric arc, becoming at last a liquid mirror in which the white-hot tips of the carbon poles were reflected. An experiment, that appeared new to most of the audience, consisted in dipping the end of an iron rod into a glass tank filled with salt and water, and containing a lead plate; the plate and rod being connected respectively to the positive and negative terminals of a direct-current supply. Directly the rod touched the liquid an electric arc was formed and in a few minutes the end of the rod was heated to a bright red; there being no danger of oxidation as the heated part of the rod was surrounded by a flame of burning hydrogen produced by electrolysis from the water. The apparatus is known as the electrolytic forge and has been used for heating rivets or iron bars for forging.

The relative cost and efficiency of electrical and coal heating was considered, as this often determines whether electrical heating methods can be employed commercially.

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* Abstract of a lecture, illustrated by experiments, delivered on the 3rd March, 1909, before the members of the Canadian Mining Institute, in the MacDonald Chemistry Building of McGill University.

The greater part of the lecture was devoted to a consideration of the electro-metallurgy of iron and steel, lantern slides of a number of large scale furnaces being shown. In the electrical smelting of iron ores, as demonstrated by Dr. Haanel at Sault Ste. Marie, enough charcoal or coke is used for the chemical work of reducing the iron oxide to the metallic state, but the heat necessary for the process is obtained from electrical energy. Recent advances have been made in Sweden by Messrs. Gronwall, Lindblad and Stalhane who spent $100,000 in three years in preliminary experiments and finally constructed a furnace of 1,000 H.P., which was visited by Dr. Haanel during the winter.* This furnace (see Fig. 1) consists of a smelting chamber with arched roof, into which are introduced the ends of three electrodes connected to the cables from a three phase source of electric current. Above this chamber is a shaft, in which the ore mixed with charcoal or coke, is heated in a reducing atmosphere for the purpose of reducing the iron oxide to metal before it reaches the zone of fusion in the smelting chamber. A circulation of gases in the furnace is effected by pumping in, just below the roof of the smelting chamber, gases withdrawn from the top of the shaft. These gases serve to cool the furnace roof and to carry a part of the heat from the smelting chamber up the shaft, thus assisting in the reduction of the ores in this part. The heat in the smelting chamber is of course generated by the passage of the electric current between the three electrodes shown in the figure; and the usual provision is made of a cup and cone for charging, and a tapping hole for removing the slag and metal from the furnace. Mr. Louis Simpson, who is interested in the Swedish Company, kindly lent the drawing from which Figure 1 has been prepared. He intends to put up an electric iron smelting plant in Canada in the near future, using this type of furnace. The plant would contain seven furnaces of 2,500 horse power each.

The production of steel is carried on in two types of electric furnace, the arc furnace and the induction furnace. The arc furnace resembles an open-hearth furnace with one or more carbon electrodes entering through the roof; electric arcs being maintained between the ends of the electrodes and the slag lying on the metal.

* This furnace has been described by Dr. Haanel. Trans. American Electrochemical Society, vol. XV, 1909, p. 25.

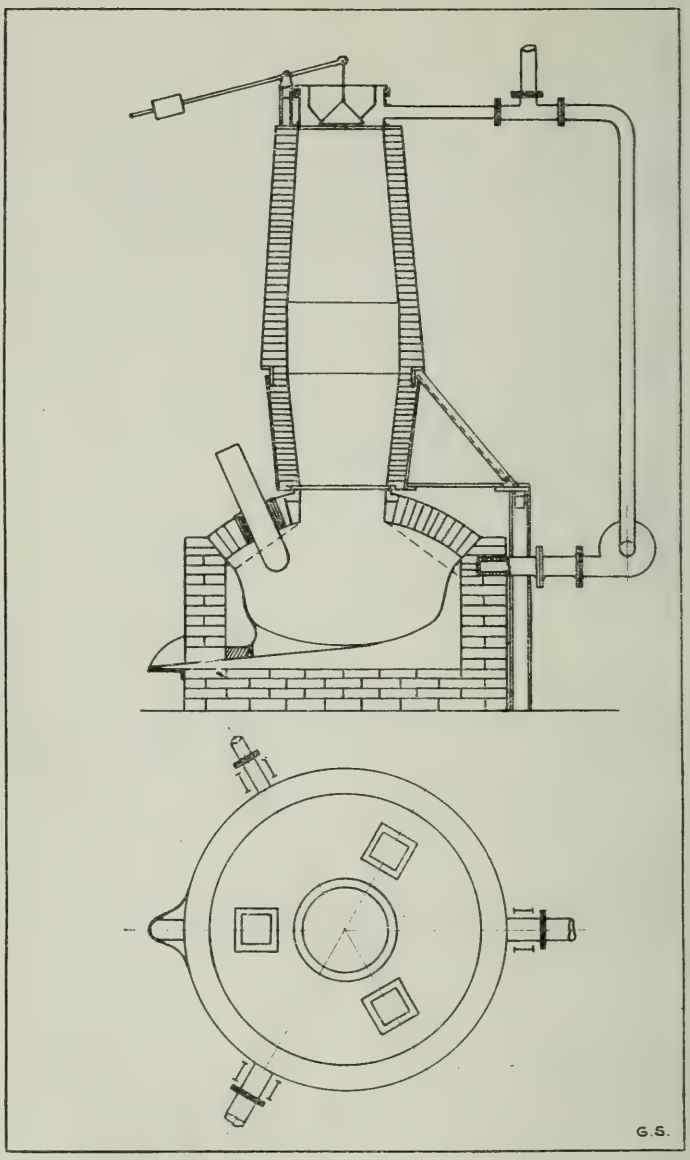

Fig. 1
Swedish Electric Furnace for Smelting Iron Ore.

In the Heroult furnace two electrodes are employed, and the electric current enters the furnace by one of these and leaves by the other. The Girod furnace on the other hand is provided with metallic connections in the bottom of the furnace so that the molten steel can be made one electrode, while one or more carbon rods entering through the roof are connected together and form the other electrode. These furnaces were used at first for making steel from pig iron, scrap and ore in the same way as in the open-hearth furnace, but more recently they have been employed merely to finish steel that has been made in the Bessemer converter or open-hearth furnace. The decarburized steel is poured into the electric furnace and is further purified by the addition of limey slags which remove the phosphorus very completely. After removing the phosphoric slags the steel is recarburized and kept in the furnace until any sulphur has passed into the slag as calcium sulphide, and until the dissolved oxides have been completely eliminated. The removal of sulphur is effected in the same manner as in the iron blast furnace, but more perfectly, as there is so much less to remove and on account of the high temperature and basic slags employed in the electric furnace. Steel can be finished and improved in this way at a moderate cost and has even been used for rail making, more than 1,000 tons of steel rails having been made in this way and sold to the German Government prior to August, 1908. The complete removal of sulphur and dissolved oxides from the steel constitutes the most important advantage of the electric furnace as compared with the open-hearth.

The induction furnace is in principle an electric transformer, the secondary of which consists of a horizontal ring shaped trough containing the iron or steel to be melted. An alternating current of many thousand amperes at only a few volts is induced in this ring of metal and produces enough heat to melt it and keep it molten while iron or steel scrap is added to give the correct composition to the steel. Compared with the arc furnace the induction furnace has the advantages of dispensing with carbon electrodes and of being able to use electrical current at a higher voltage. It has the disadvantages of a low power factor, owing to the magnetic leakage between the primary and secondary circuits and of having a very narrow channel to hold the molten steel,

which renders the furnace unsuitable for refining. A modern form of induction furnace, the Roechling-Rodenhauser, has overcome these drawbacks to a considerable extent. In this furnace the secondary consists of two nearly circular rings which meet, forming an 8. The channel is very much widened at the point where the rings meet, thus forming a large basin in which the refining of the steel can be effected as in the arc furnace. The electric current flowing around the rings of molten steel would not heat sufficiently the larger body of metal at the point where they meet, and the additional heat needed is furnished by means of steel "pole pieces" which are embedded at suitable points in the walls of the furnace and being connected to special secondary windings on the core of the transformer, supply additional current to the steel in the central part of the furnace. The pole pieces do not actually touch the molten steel but are separated from it by a part of the magnesite lining. This material is a non-conductor when cold, but when the furnace has been heated up by the current flowing in the rings, the lining becomes an electric conductor and admits the additional current to the furnace.

The furnace just described would be operated by single phase current, but by a further modification it can be made suitable for three phase current and thus rendered more applicable to ordinary conditions of electrical supply.

The Roechling-Rodenhauser furnace, like the arc furnace, is mostly used for finishing steel that has been made in the Bessemer converter or open-hearth furnace. For this class of work, an induction furnace of 1,000 H.P. requires a power of about 90 K.W. per ton of capacity and consumes about 150 K.W. hours per ton of output, when making rail steel.

After the lecture, a 10–20 K.W. induction furnace of the Colby type was shown in operation in the metallurgical laboratory. The furnace, which holds 30 or 40 lbs. of steel, can be tilted by gearing and the metal which had been previously melted was poured into moulds before the audience. A small arc furnace was also shown in operation.

Later note, July, 1909.—The 20 K.W. Colby furnace was loaned for the lecture by the American Electric Furnace Company of Niagara Falls, and was operated by a temporary line from an

experimental dynamo in the Electrical Laboratories at McGill. Through the generosity of Dr. Milton Hersey, the furnace has now been purchased for the Metallurgical Department, and a 30 K.W. motor-generator set with transformer and necessary instruments will shortly be obtained for operating this and other furnaces. This equipment, which has been badly needed for a long time, will supply 30 K.W. of alternating current at almost any voltage that may be required, and will enable electric furnace experiments and researches to be carried out on a satisfactory scale.

LEAD SMELTING AND REFINING PRACTICE AT TRAIL, B.C.

By A. J. McNAB.

The Trail Smelter was built by Mr. F. August Heinze in 1896, to treat Rossland copper-gold ores only. In 1898 it was acquired by the Canadian Smelting Works. The new management at once began enlarging the capacity of the plant, and in 1899 installed the lead smelting department. This, in accordance with the standard practice of the time, consisted of hand and Bruckner furnaces for roasting, and rectangular blast furnaces for reduction. The plant consisted of three blast furnaces, ten hand roasters and six Bruckners. At this time no refinery was built, the bullion being shipped to San Francisco, where it was refined in bond. In order to save the heavy freight and refining charges, it was decided to build a refinery, and, in 1902, after careful experiment, the Betts Electrolytic Process was installed, the capacity being ten tons. This was enlarged successively in the years 1904 and 1905 to 20 and 50, and in 1906 to 75 tons – its present capacity. During this time the main changes in the smelting department were the abolition in 1906 of the hand roasters and Bruckner furnaces and the installation of the Huntington and Heberlein roasting furnaces and converters, the first installation being two Huntington and Heberlein roasters and twelve converters. In 1907–1908, four more roasters and twelve more converters were added, and two additional roasters are now being built, making eight in all, with twenty-four converters.

The ore supply is obtained from all parts of the province, Trail being the only customs smelter; in fact the only lead smelter in operation in British Columbia at the present time. The main supply comes from the St. Eugene mine, East Kootenay, owned by the Consolidated Mining & Smelting Company. This mine supplies about 75% of the total lead produced. The remaining 25% is almost entirely derived from other mines in East Kootenay and

the Slocan districts, the lead tonnage produced from other sections being a negligible factor.

The ores are mainly sulphide, 80% being heavy galena ore or concentrates, running from 45% to 75% lead. The tonnage of oxidized lead ore is small, not being over 10%, while the balance of the tonnage is dry gold and silver ores with some gold concentrates from stamp mills. This preponderance of heavy sulphide ores necessitates a marked difference in policy from that followed by other lead smelters on this continent, as the conditions outside this province usually furnish the reverse features, viz., a comparatively small tonnage of heavy galena ore and concentrates, and a large tonnage of dry ores, iron concentrates, etc. This, as will be noticed later, compels a high percentage of lead on the charge, 35%–45%, as against the common practice of 10%–15%.

Sampling and Bedding:- The oxidized lead and dry ores are sampled in a mill equipped with Vezin samplers, crushing the sample to $\frac{1}{4}''$ and the reject to a 6″ ring. This reject goes direct to the lead furnace charge bins. The heavy galena ores and coarse concentrates are crushed to $\frac{1}{4}''$ and bedded, the sample being taken with Vezin samplers as above, 1/500th being the amount cut out. The fine concentrates are usually sampled by the fifth shovel method and bedded direct. In bedding it is aimed to secure a mixture with about 50% of lead, only ore being bedded; lime rock, lead matte and a small amount of the ore (which, with the beds, constitute the roaster charge) is added later. At one time it was the practice to add the necessary amount of lime rock and matte to the beds; but on account of the beds freezing in winter, which rendered a uniform mixture impossible, the extra expense of handling, together with a want of elasticity, which rendered a sudden change in the charge difficult, it was abandoned. The beds are large flat bins with a capacity of from 600 to 700 tons and are provided with tracks, etc., to enable the ore to be spread out in layers of a uniform thickness, so that in smelting the bed a fairly constant mixture shall be obtained.

Making up Charges, Mixing and Roasting:—The charge for the H. and H. roasters requires to be made up with a certain content of lead, iron, silica and lime to work well in the roasters and converters, and later in the blast furnace. In fact, the roasting department is the most important part of a lead smelting works:

and the experience here has been, that with a good roast, there is little or no furnace trouble, whereas with a bad roast furnace complications are considerable. We find that for our usual conditions the most economical roast will analyze about as follows:—

Lead 40–44%; iron 10–13%; silica 8–11%;
lime 7–10%; zinc under 10%.

This material when properly mixed, roasted and converted will give a fairly hard, dense product of a yellow or grayish-yellow colour, showing considerable litharge; will make but little fines and will be fairly easily broken. It will run fast in the blast furnace with a cool top, clean slags and bright tuyères. We have found some difficulty in getting a good roast with over 45% lead in the roaster charge, the sulphur being usually high; but we have not had occasion to try it since installing the mixer, and that might make some difference. The difficulty seemed to be that in places the charge would not be sufficiently stiff, the galena fusing before roasting much, and in the fused condition, it is almost impossible to roast it. With a properly mixed charge this might not occur and several per cent. more lead might be carried. We have never had occasion to run our lead lower than 38% over any lengthy period. This gives a good product if the other constituents are properly proportioned; in fact, a 38% product is, we think, preferable to 42%, as it runs a little faster and gives less trouble. If our ores were suitable, we would run about 38%–40% lead, as on the whole it would be a little more satisfactory, being, for example more easily broken. But this difficulty is not so great that it would pay us to dilute our charge with ores carrying a low treatment rate. The iron ought at the least to be as high as the silica, and it is better to have it one or two per cent. higher. We have been compelled at times to run our roast with from 2% to 3% and even 4% higher silica than iron and we have always had trouble. It did not seem to interfere with the sulphur elimination at all, as that would be as good if not better than ever; but do as we would, the tonnage would fall off badly, the slags would get higher in lead and there was a great tendency for the heat to get up in the furnace. We varied the rest of the blast furnace charge in every way we could think of, carried our lime in the slags high and carried it low, tried the coke higher and lower, varied the amount of slag, changed

the feeding and the blast but with no very decided improvement. But on changing the analyses of the roast, all our troubles would disappear in a short time. The only explanation that we can see is that the high silica roast was too fusible, fusing too high in the furnace, which would cause the bad reduction, hot top, and slow running. We have no data on the relative fusing temperatures of the two roasts, and consequently have no facts to base our assumption on, but it seems to be the only one to fit the results and one would imagine the higher silica roast would have a considerably lower melting point. This would be a rather interesting but a difficult point to determine on a small scale, as it would be hard to get the roast sufficiently uniform so that a small piece would accurately represent it. However, if a series of determinations on each kind were made, the averages would probably be very nearly correct.

We run the lime between 7% and 10%. This, with our conditions, represents about the limits. We have never obtained good results with the lime below 7%; as a rule we run it about 8% to 9%. However, if we had suitable ores to enable us to keep our iron up, that is to keep about the same total percentage of iron and lime, and keep the lead down to 42%, it might work well. We have never had ores to enable us to try this, as we are somewhat short of iron and are compelled to use lime to keep our lead down. Another reason is that the product is difficult to break when the lime gets too low. We have never run the lime higher than 10%; in fact, we always keep it as low as possible, because it is not economical, as we have to add most of our CaO as $CaCO_3$, which has to be charged with the cost of roasting.

The roaster charge is accurately figured and carefully weighed, being made up with bedded ores, lime rock, stamp mill concentrates and matte, from the furnace, that is too high in lead and too low in copper to be concentrated. This charge is put through a cylindrical mixer, one mixer handling the material for four furnaces. This discharges the material into an elevator, discharging into chutes which convey the material to the furnace feed hopper.

The roasting department has six 26′ circular H. & H. furnaces, with two more building. These furnaces have revolving hearths, making one revolution in three minutes, and stationary cast-iron rabbles, which work the material out of the furnaces in two hours.

They have one firebox 6′ x 3′ on the periphery, the feed coming in the centre, thus gradually approaching the hotter part of the furnace. The material goes into the roasters with from 14%-17% sulphur and comes out with about 8%-8.5%. The capacity is from 38 to 45 tons per day, depending on the amount of sulphur in the material charged and the elimination desired. Our experience is that for good desulphurization in the pots the roast should not have over 9% sulphur, 8% being much better. The temperature of these furnaces must be carefully regulated so that there may be heat enough to roast the charge properly though not enough to fuse it, as this will rapidly crust up the furnaces. The roast should consist of small uniform semi-fused globules showing neither lime rock nor ore. The furnaces discharge into the boot of a chain elevator, which drops the roast through a spray of water into a brick bin. This spraying of the roast is a very important part of the process, as it would be impossible to obtain a good product in the pots without doing this, the principal part would then consist of fines which had not fused at all. The function of the moisture (the roast should have about 5%) seems to be a mechanical one, preventing the blast from blowing through too freely, thus making blow holes and localizing the heat. It keeps the heat in the pots until they start to burn uniformly and the temperature gets sufficiently high to insure thefusing of the charge.

The roast is conveyed in cars from the brick bins to iron hoppers over the converters. The lead converting plant consists of 15 converters 8′ 8½″ in diameter, holding a charge of 10 tons each. The diaphragms used are cast iron, cast in four sections and bolted together; these sectional diaphragms are much more serviceable than those cast in one piece, as the expansion and contraction is taken up in the joints, and they do not crack. Cast-steel diaphragms were tried but proved a failure as the heat bulged them. The converters are operated as follows: A few slabs are thrown into the converters with a shovelful of glowing coals from the firebox of the roasting furnace, a small blast turned on until the fire burns briskly, then the converter is filled from the hopper above, a blast of from 6-8 oz. being turned on and gradually reduced, until when the fire is at the surface and the charge nearly burned only about 2 ozs. is used. Instead of using slabs for starting it can be done with a hot charge--whichever method is preferred. When the

charge is burned out, which takes on the average about 8 hours, the converter is dumped and the fused mass falls on a cast-iron cone, which breaks it into several large pieces. These are broken small enough to enter a 20 x 20 Blake crusher, which crushes it to a 6″ ring. The product is elevated from this crusher and goes direct to the furnace charge bins.

The heat, used in pot roasting is, of course, supplied by the oxidation of the sulphur, iron, etc., in the charge. The reaction between the sulphides, sulphates, and oxides doubtless aids considerably in the elimination of the sulphur, but just to what extent it is difficult even to guess. Some lead is always reduced, the amount varying a good deal, being higher with a high percentage of lead. The function of the lime in the roasting and converting is a much disputed point on which the writer will not venture to express an opinion. Of course, roasting and converting can be done without any at all. We regularly roast our low grade copper matte with say 15% copper, 27% sulphur, and 56% iron, in an O'Hara or Godfrey furnace, down to 10-12%, and then convert it in H. & H. converters of the usual type, getting a good product carrying from 1-3% sulphur. We also treat mattes carrying up to 25% lead in the same manner, and obtain a good roast, though the product is more massive and is harder to break. So that if the lime performs any peculiar chemical function it is one that can be performed as well by iron.

The blast furnace plant consists of two furnaces, one 45″x140″, with an average capacity of 150 tons of ore per day, one 45″x160″, with an average capacity of 170 tons. Another furnace in the process of construction is 45″ x 215″, which we anticipate will put through 240-250 tons of ore daily. In speaking of capacity, we refer to tons of ore, instead of tons of material smelted, as is the general practice on this continent. The general practice in this particular, is very misleading, and in fact, conveys very little information, as flux, matte, slag and other bye-products might vary anywhere from 15-40% of the charge. For instance, one day our 45″ x 160″ furnace smelted 181 tons of ore, but 261 tons of charge, exclusive of fuel. Another day it made about the same ore tonnage—180—and only made 230 tons of charge. In the first instance the charge carried a lot of bye-product, 31%, in the second only 21% with the same ore tonnage. The capacity of the furnace

should really be figured on the revenue it produces, and as bye-products carry no revenue, they should not be figured.

The furnaces are of the standard type with brick crucibles, and are water jacketed from the crucible to the top of the bosh, above which is a firebrick shaft. The smaller furnace has fourteen 4″ tuyères, all in the sides of the furnace and the larger one has sixteen tuyères. The tuyères are 20″ centres; but we are reducing the distance on our new furnace, making it 15″ with smaller tuyères. The height of column, measured from tuyères to feed floor, is 17.5′ and the blast used is 32 oz. The lead well is of the continuous overflow type and the matte and slag are tapped from the furnace, the matte settling out in a large receiver and the slag overflowing into the granulating launder.

The furnace charge consists principally of H. & H. roast, which is never under 75% and averages 85% of the charge. Besides the roast, the charge carries a small amount of oxidized lead ore and sufficient dry silicious ore and lime rock for the slag desired, also from 100–300 lbs. of furnace slag to keep the charge open and the furnace uniform. The coke averages about 12.5% of the charge, exclusive of slag and easily smelted bye-products, varying with the roast and the quality of the coke. The lead in the charge will average about 40%, excluding coke and slag. We have run as high as 45% and with good roast, that is, suitable analysis and low sulphur, no trouble is experienced. But if conditions are imperfect, especially if the sulphur in the roast gets high, trouble begins at once, the slag gets "mushy" and will not run, and if something is not done the furnace will stop. High sulphur is bad at any time, but with a high lead charge it cannot be tolerated, as it is not possible to smelt such a charge economically. For a 40–45% lead charge, the sulphur should not exceed 4% and is much better if only 3%. Even with no serious furnace trouble like a threatened freeze-up, the lower the charge in sulphur, the faster it will run for the same analysis, and of course the lower the matte fall, thereby saving money. The difference in speed between a roast of the same analysis, high in sulphur and low in sulphur, is very marked, and a change in the amount of sulphur in the charge, corresponding to a difference of 2% in the matte fall, will easily make a difference of 10–20 tons of ore smelted per day. The sulphur elimination in our blast furnaces, with a fairly close charge

will be from 30–40%, due to a considerable extent to reactions between sulphides, sulphates and oxides.

The slag aimed at is a modified $\frac{3}{4}$ slag, FeO + MnO 24–30%, SiO_2 31–33%, CaO 18–20%. No attempt is made, however, to follow any definite slag type, as no advantage is apparent from doing so. We try to keep our silica from 31–33%, as we find that by going below 31% we do not gain in speed; in fact, the slag is sticky and does not tap so easily and we can profitably smelt silicious ore to keep it up to this. Above 33%, however, we find it slows up the furnace so that the extra silica is no longer profitable. The FeO may vary anywhere from 25–30%, without varying either the speed of the furnace or the slag loss, the lime between 18 and 20%, though the lead in the slag gets less with the higher lime, but the difference is small. We do not like to run our lime higher than 20%, as the breast gets hard. This is dangerous with a fast running furnace, as a little carelessness will slag the tuyères. When the charge gets high in sulphur the lime is reduced at once to 17–18%, as lime accentuates any trouble due to "mushy" slag. Also if the slag gets high in zinc the lime is reduced proportionately. The zinc runs from 7–12% Zno, giving us little trouble if not over 12%, alumina runs from 8–16% with an average of about 11%; when it gets high (13–16%) it seems to make a heavier, less liquid slag and slows the furnace up, but at no time have we had any serious trouble from this element. In values, the slags average about 0.4 oz. silver per ton and 1% lead.

Usually scrap iron to the extent of 1–1.5% of the charge is used, this helping very materially in the reduction. If this is not used the slags are higher in lead, though the silver content is not raised. There is a tendency to higher slags with a faster running furnace, especially higher values in lead. That is, a furnace putting through 125 tons of ore daily will run cleaner slags than the same furnace running 160. That is, provided the roast and other conditions of charge are not so bad as to prevent reduction. High sulphur in the charge will cause slow running but will also cause high slags. This would not be expected since sulphur is a powerful reducing agent. The reason probably is that a high sulphur charge causes the jackets to crust badly and accretions to form higher up the shaft, making the furnace hang and smelt too high up, curtailing the opportunity for reduction. Our furnace cam-

paigns average 6–7 months. Accretions form on the shaft of the furnace, gradually filling it up, generally beginning on the ends and growing towards the centre. In six or seven months time they have usually grown so that while the furnace may be, and usually is, smelting as much if not more ore than at the beginning with good slags, yet the area of the upper part of the shaft is so restricted that the heat comes up very readily if not carefully fed and increases the volatilization loss so that it is more economical to blow them out. About 70 tons of bullion per day is produced by one furnace. This runs from the lead well into steel coolers, two being provided for each furnace with a capacity of about 3 tons each. The bullion is cooled and drossed here, the dross being skimmed off and put back through the furnace, the bullion is tapped into moulds which make pigs of about 90 lbs. weight; these are sampled and sent in railroad cars to the refinery. An average monthly analysis of the bullion is as follows:—Cu. 22%; Fe. tr.; Mn. nil; Zn. 0.098%; Sb. 0.32%; As. 0.28%; Ni. nil; Co. nil; Cd. nil; Bi. 0.0133%; Ag. about 100 oz.; Au. 1 oz.; Pb. 98.5%. Arrangements are now being made to cast the anodes for the refinery direct from the cooling kettles, thus saving remelting.

Refinery Melting Plant:—The bullion from the smelter is melted in 50 ton steel kettles and pumped by a centrifugal pump into a receiver from which pipes, with plug valves, lead to 10 vertical anode moulds. A $1\frac{1}{2}''$ cast iron pump of the ordinary type is used and is driven by a 2 h.p. electric motor. The moulds are filled by opening the valves, the speed of discharge being regulated easily with these. The moulds are of steel, immersed in water to keep them cool, and have a movable head which forms the head of the anode and is lifted out, carrying the anode with it. The head is freed from the anode by the blow of a hammer and reset in the moulds ready for another tap. The anodes are handled from the moulds to cars by a crane; the cars hold ten anodes, set vertically, and are run into the tank room, two cars are placed together, and the 20 anodes lifted off at once by a 10-ton electric crane and placed in the tanks, each tank holding 20 anodes. The cathodes are melted in two 50-ton steel pots; the lead, after skimming, is raised by a centrifugal pump into a receiver, flowing from there by a movable spout into a circle of moulds, making pigs of about 100 lbs. weight. The lead is all moulded into pigs of this size

with the exception of that for the Chinese trade, which is made into pigs of a special form, weighing 180 lbs.

The cathode starting sheets are also cast in this building. In the early days of the plant, these sheets were made electrolytically, a thin sheet of lead being deposited on paraffined steel sheets in tanks set aside for this purpose and operated at a low current density. When the deposit of lead was of sufficient thickness, the cathodes were taken out, the sheets stripped off, flattened out, rolled on cathode bars and were ready for use in the tanks. This method was found to be not only costly, but to give weak unsatisfactory sheets. It was found that if lead was poured on an iron or steel plate, with a smooth surface and inclined at an angle, it would chill as it flowed down the plate, giving a nice, uniform sheet, the thickness depending on the temperature of the lead and the angle of inclination of the plate. The starting sheets have now been made on this principle for some years, giving a much cheaper, and a more satisfactory sheet in every way than by the old method. The casting machine is very simple, consisting of a $\frac{3}{4}''$ steel-surfaced plate the size of the starting sheet, set at an inclination of 1.8 inches per foot. An iron trough of more than sufficient capacity to carry the lead necessary for one sheet is hinged at the higher end. Enough lead is ladled from the pot into this trough, which is then turned up so that the lead will flow down the plate, forming the sheet as it flows, the excess spilling over. The sheets are trimmed, very little trimming being necessary, and lifted from the machine on to a car and the machine is ready for the next cast. The sheets are taken into a special room at the south end of the tank department and there straightened and hung on $\frac{1}{2}''$ x $\frac{3}{4}''$ copper bars by just bending the sheet around the bar once. They are then placed on a car holding 21, sufficient for one tank; of course the sheets are suspended by means of the copper bars from frame work built up on the car so that there will be no danger of them getting bent. These sheet-cars are run on tracks between the different rows of tanks and the sheets are put in by hand.

The tank room contains 240 tanks of 3′ x 8′ x 3′ 6″. These are made of 4″ coast fir, lined with asphalt and give very good satisfaction, leaking but little. They are arranged in 6 rows of double tanks, running the length of the tank room, and in three

series of cascades; one cascade of nine tanks in length on one side of the pump room launder, and two cascades of six and five tanks in length on the other side. The pump tanks which are near the centre of the building are built of fir, and are asphalt lined, similar to the electrolytic tanks. The solution flows from the last tanks of each cascade in an asphalt lined launder to the lower pump tanks, the pumps raising the solution from these into tanks set high enough so that it will have plenty of head to carry it to any part of the building. $1\frac{1}{2}''$ hard rubber pipes carry the solution from these tanks to the first tanks of each cascade, $\frac{3}{4}''$ pipes conveying the solution from tank to tank. The circulation enters the tank at the top and leaves it at 7″ from the bottom.

Each tank has 20 anodes and 21 cathodes, the latter being a little longer and wider to prevent short circuiting. The tanks are normally operated with a current density of 16 amperes per sq. ft. of cathode area, requiring, with 12% SiF_6 and 5% lead in the solution, a voltage of 0.32 per tank including all contacts. The loss of voltage in the contacts is small, being about 0.02 in all. The anodes are set with $4\frac{1}{8}$ inch centres, the cathodes being set midway between. Only one crop of cathodes is taken at present, two having showed no advantage. With a normal current density a tank is worked out in eight days, about 15% of scrap going back to the melting pots. Most of the slime adheres to the anode scrap. This is scraped off in a special tank, the scrap washed and returned to the melting pot. Some slime, of course, falls off in the electrolytic tanks, these being cleaned out once a month. The current efficiency is from 85% to 90%, the losses being due to short circuiting in the tanks, and to floor leakage.

The electrolyte used is, of course, lead fluosilicate with free fluosilicic acid. The average composition will be about 12% SiF_6 and 5% to 6% lead, having a specific gravity of from 1.17 to 1.19. This gives a stable electrolyte, the losses being small. Losses are due to leaks, to solution not worked out of the slimes and to chemical decomposition of the solution, H.F. and SiO_2 being formed. Some loss is probably also experienced in the evaporation of the wash waters, though H_2SF_6 is supposed to concentrate to a high percentage, with no loss at the temperature used. The H_2SiF_6 used is made at the plant; CaF_2, H_2SO_4 and SiO_2 in the proper proportions being mixed and heated in a closely covered,

large cast iron pan. The fumes are passed through a series of towers, having at first a spray of water and later dilute acid descending. This H_2O unites with the fumes forming H_2SiF_6, the charge being so proportioned that sufficient H.F. is generated to dissolve the H_2SiO_3 formed. The solution is kept circulating until it is of sufficient strength, usually 30% SiF_6, the little H_2SO_4 it contains being taken out with lead dross, and the clean acid added to the electrolyte as required.

Under proper conditions, little trouble is experienced in making good lead. An average monthly analysis, representing about 2,000 tons, is as follows: As., nil; Bi., nil; Zn., 0.0005%; Ag., 0.0013%; Cu. 0.00075%; Pb., 99.9938%; Fe., 0.00075%; Sn., 0.0001%; Sb., 0.0028%. The silver runs from 0.1 to 0.5 oz., attributable to small particles of slimes floating over to the cathode, settling on the projections of the latter and being plated in. As a general rule, the smoother the deposit, the freer it is from impurities. The first deposit on the sheet is usually very smooth, getting rougher as the cathode gets heavier. The smoothness of the deposit varies with the voltage, the lower the voltage, the smoother the deposit; it also depends somewhat on the amount of glue used. From 0.5 to 1 lb. of glue per ton of lead produced is added to the solution daily. The function of this glue does not seem to be understood beyond that a reducing action is required. If no compound like glue is used, the lead deposited will be spongy, soft, and not coherent. In fact, it would be practically impossible to operate, as the tanks would all short circuit within a very short time.

The slime from the tank room is transferred in copper cars, to the wash tanks, and agitated with hot water, the wash waters resulting from this operation being evaporated in steam coil evaporators to the specific gravity of the electrolyte and returned to the tank room. The slimes are practically washed clean, the loss of electrolyte due to retention being very small. After washing, the slimes are filtered, dried in large cars, by being run into the furnace flue, and charged into a water-jacketed reverberatory furnace, lined with magnesite brick. An analysis of the slimes would be Ag., 35%; Sb., 25%; As., 20%; Cu., 8%; with a small amount of Fe, Bi, SiO_2, and at times traces of Te and Se. The impurities are oxidized off and doré metal 960-975 fine silver+gold, results. This is ladled into moulds and parted with sulphuric

acid, the silver being shipped 999 fine and the gold 995. The bluestone manufactured as a bye-product is 99.5%, $CuSO_2$, $5H_2O$. At present neither the antimony nor the arsenic are recovered. They were recovered for some months, a year ago, but owing to the fact that the percentage of antimony in the bullion has dropped from 1% to 0.3%, and the price of antimony from 25c. to 7c., it is no longer profitable. However, the plant is arranged that this may be done when conditions require it. The process is as follows: The slimes are boiled with sodium polysulphide, which extracts from 80% to 90% of the antimony and 50% of the arsenic. The slimes are filtered, the solution electrolyzed in iron tanks, having lead sheets as anodes and steel sheets as cathodes, using a cathode density of 8 amperes per square foot with a normal voltage of 1.5 per tank. The antimony deposits on the steel sheets and on the tanks, which are also connected as cathode; dense, hard deposits up to $\frac{1}{2}''$ in thickness being obtained. When the deposit begins to loosen on the sheets, they are lifted out, the antimony scraped off and the sheets returned ed to the tanks. The antimony contains up to 2% arsenic, which is taken out with alkali fluxes, when it is melted for casting. The solution goes into the tanks with 4.5 grams antimony per 100 cc's, and comes out with from 0.5 to 1 gram. It is then sufficiently concentrated in steam coil evaporators, to make up for any increase of volume of the solution due to the agitation with steam, and used again with the addition of a little more sulphur for treating a fresh batch of slime. During electrolysis some of the Na_2S_x is oxidized to sodium thiosulphate; this loss amounts to, about 30 lbs. of 30% Na_2S per ton of bullion carrying 1% of antimony, if no regeneration is used. Regeneration may easily be effected by crystallizing the sodium salts out of the spent solution and reducing to sulphide with carbon.

The slimes, after treating with Na_2S_x, are filtered, roasted in a furnace of the muffle type and treated with 10% H_2SO_4, which extracts 90% of the copper and from 10% to 75% of the silver, depending on the thoroughness of the roast. The solution, after filtering, is boiled with copper plates to precipitate the silver, and used again, or if the copper content is sufficiently high, is pumped to the bluestone plant for crystallization and recovery of the copper. The residue is melted in an oxidizing atmosphere with a little coal or silica to break up the $PbSO_4$, doré bullion of 950 to 960 fine resulting, which is parted as usual with H_2SO_4.

MINING METHODS AND EQUIPMENT AT THE BRITISH COLUMBIA COPPER COMPANY'S MOTHER LODE MINE.

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The following is a brief description of the system of mining and equipment at the B.C. Copper Company's Mother Lode mine, Boundary district of British Columbia.

At this mine there is one distinct ore body, which already has been opened by four levels, work on a fifth having been only recently started. The orebody is a contact deposit between limestone on the foot-wall, and greenstone on the hanging wall; the dip being about 70° to the east and the strike northeast with a southerly pitch. Most of this ore has been formed by replacement and alteration in the greenstone, the limestone being as a rule but little affected.

Several dykes of porphyry, from one to twenty feet thick, intersect the ore at approximately right angles to the dip, and frequently prove troublesome in mining. East of the quarries the ore is covered with a flow of later, and barren, eruptive rock, which has limited the width of the quarries to about half that of the orebody.

The ground is very firm and stands well—a fact of the greatest importance in the operation of the mine, and without which it would be impossible to maintain in safety the large open spaces underground.

All four levels are connected by stopes and raises. On each level are parallel drifts from about 50 to 70 feet apart, connected by crosscuts and drifts run at various angles, thus allowing ore trains to pass each other at different parts of the mine. The first drift is along the footwall of the ore body, the second in the centre, and the third close to the hanging wall. By this method any number of trains may be conveniently handled on the level.

Chute raises are begun at intervals of 35 feet apart, every alternate chute being placed on the opposite side of the drift. By this arrangement the stopes on each level are easily connected, and the chutes also serve for ventilation purposes. The chutes are started in the same manner as a raise; after raising 8 or 10 feet a beginning is made to funnel them on all sides at an inclination of about 35°. When several connect with one another the stope is extended, leaving pillars at convenient places. This preliminary work having been done, the stopes are carried to the next level above in a series of large spiral raises. After connecting the levels, tripods are used in the bottom of the stopes.

When any level is thoroughly connected with the next lower level by means of these spiral raises, the ground is then in such shape for caving that work can be started at the farthest point from the shaft and the pillars between the spirals blasted down, allowing the ore to drop to the level below. In this way the level is kept safe while the work is progressing on the other levels.

The large quarries, of which there are six, are all connected with the 60-foot level, while in one place, connections are made with the 200-foot level. This has been found a great advantage, as the ore, falling so far, is thereby broken much finer, effecting a great saving in powder for bulldozing and involving much less labour for the chutemen and skipmen in handling the ore.

The ore is conveyed to pockets at the shaft in cars drawn by horses. Two types of cars are used. On the lower levels the cars are 3-ton side-dumping; on the 60-foot level trains are loaded of three and four 3-ton scoop cars. An automatic dump unloads them at the pocket. A chuteman with a helper loads the ore from the chutes. In case a chute gets blocked he does the necessary blasting to clear it. The chute openings are 3 x 4 feet, and are built of heavy round timbers. The bottoms and sides are 4 x 10-inch timbers lined with $\frac{1}{4}$-inch steel plate. The collar braces are covered in the same manner. Two descriptions of gates are used—one a circular iron chute gate, and the other the old style chute boards.

The shaft is vertical with four compartments, each compartment being $4\frac{1}{2}$ x 5 feet. Two compartments are used exclusively for ore, one for lowering and hoisting the men, and the fourth for ladder and pipe way.

Connected with the shaft are large storage pockets at each level, from which the ore is hoisted by two skips, each holding four tons, these being loaded by means of finger gates operated by compressed air.

One 20 x 36 Jenckes hoisting engine is used. It is easily capable of hoisting the skips 400 feet per minute, or 60 skips per hour, from the 400-foot level (the deepest now opened), or at the rate of 240 tons per hour. The cage is operated by one independent 80-horse-power single drum hoist and is counterbalanced by sliding weights run in the ladder compartment of the shaft.

There are two compressors, one a 16 x 25 x 36 D, 2. T. Rand engine, capacity 3,400 feet of free air per minute, and one Ingersoll-Sergeant machine of 2,800 feet capacity. The Rand is driven by a 600-h.p. Canadian General Electric motor and the Ingersoll by a 500-h.p. Westinghouse motor.

The writer has devised what has proved to be a most satisfactory system for separating the moisture from the compressed air, consisting of a 100-h.p. boiler submerged in a tank of water. The air passing through the boiler is cooled and the moisture drawn off. After once being filled, only a small quantity of water is required to keep the tank cool.

There are two crushers, one a 36 x 42-inch jaw opening, and the other a 16 x 34 Farrel-Bacon machine. These are connected with a 100-h.p. motor and a 100-h.p. steam engine, so arranged that either can be driven by steam or electricity at will, which arrangement effectually guards against failure of crushing operations. After crushing the ore, it is conveyed to the shipping bins by means of a 10-ply rubber belt, 36 inches wide and 167½ foot centres. The bins have a capacity of 2,000 tons of which about half will run into the cars.

The hoisting engines are arranged so that they may be operated either by steam or compressed air. The steam is supplied by two 60-h.p. boilers. One is kept in constant use for general heating purposes. Ordinarily compressed air is used, and this is found to be considerably less costly than steam.

During the month of December the underground force at the Mother Lode consisted of 1 foreman; 4 shift bosses; 126 miners; 4 timbermen; 4 pipemen; 16 muckers; 16 chutemen and

trammers; 1 trackman; 4 nippers; 4 skipmen; 2 cage-tenders; 1 powderman, and 4 blasters—a total of 187. The total force employed at the mine, exclusive of boarding house employees, was 235. The daily average output of ore was 1,545 tons. The daily average output per man was 6½ tons for all men employed.

THE IMPORTANCE OF LOW GRADE BOUNDARY ORES IN THE COPPER PRODUCTION OF CANADA.

By A. B. W. Hodges, Grand Forks, B.C.

Western Branch Meeting, Victoria, September, 1908.

The Boundary district first became productive of copper in the year 1900; but it was not until the following year that this young and low grade area began to considerably contribute to the copper production of Canada.

During 1900 the Province of British Columbia produced about 10 million pound of copper, while in 1901, 27,600,000 lbs. were produced, due almost entirely to the increased production of the Boundary mines. Since then, the total production of copper of this Province made annual advances, until the year 1906, when nearly 43 million pounds were produced and of this amount over 32 million pounds was the product of the Boundary mines. The copper production of the Boundary in 1907 was within half a million pounds of the previous year, the decrease being ascribable to the shutting down of some of the mines in consequence in part of exceedingly low price of copper.

When it is remembered that the total production of copper in the Dominion for 1907 was about fifty-seven million pounds, it will be observed that the Boundary mines produce over one half the total copper output of this country.

The ores of the Boundary not only carry copper, but also some values in silver and gold, and during 1907 the value of these amounted to nearly two million dollars, which, together with the copper, made a combined value in ores mined in the district during that year of $8,299,288.00, or is about 44% of the total value of all metals produced in the Province.

The reason that Boundary ores are referred to as "low grade" is as follows:—The total metal values as extracted by smelting amount to from $4 to $6.50 per ton, depending on the price of

copper, the gold and silver values alone being from a dollar to a dollar and a half. In order to mine, transport, smelt and sell the metals in Eastern markets and still make a reasonable profit on ore of this low value, the natural conditions must necessarily be favourable. That these conditions are extraordinarily auspicious in the Boundary district is manifest, since in no other mining district in Canada and in only one or two places in the United States or Mexico is such low grade copper ore profitably mined and smelted.

The favourable conditions referred to apply to both the mining and smelting. In the first place the ore bodies are wide, being anywhere from 50 to 300 feet; they are also from several hundred to several thousand feet long and generally have enormous outcrops on the surface. This makes mining development comparatively simple and inexpensive, as most of the surface ore for a hundred feet or more down is mined by open pits. Then again in connection with underground mining operations, little or no timbering is required, since the natural construction of the ore and rock will hold itself, if sufficient pillars are left. The ore is reasonably soft, drills comparatively easily and breaks well.

Mining is also carried on upon a very extensive scale, employing large and economical equipment, aided also by the use of electricity in all departments. The ground is comparatively dry, thus doing away with the necessity of expensive pumping equipment. Not only are the mining conditions exceptionally favourable but so also are the metallurgical conditions. All the copper ores in this district are what is known as self-fluxing; that is, their chemical composition is such that fed into a blast furnace with little or no outside flux and with the addition of the proper amount of coke, they make a good blast furnace slag.

Again the ores carry only sufficient sulphur to make a matte suitable to convert at once without a second smelting.

Below is given an analysis of a sample of Granby ore which approximately represents the entire ore body:—

Silica	38.
Iron	12.
Lime	18.
Alumina	7.
Magnesia	7.

MnO	.5
Arsenic	.008
Antimony	.015
Copper	1.500
Sulphur	3.5
	87.523

Nowhere else in the world is found ore bodies carrying copper of approximately like analysis, nor comparable in size with those of the Boundary district, representing as they do from 10 to 30 million tons; these then are the main reasons which permit of the economic handling and smelting of these ores.

A smelter using Boundary ores alone is the most simple plant possible; since the complicated system of ore beds of different analysis which require to be mixed in the proper proportion to make an economical slag, is eliminated; and moreover as the sulphur contents is so small no expensive grinding and roasting is necessary.

In smelting Boundary ores the preliminary steps towards making blister copper, which is the final product, are few and simple. In the operations of the two largest companies the ore is crushed at the mines to a suitable size for the blast furnace, is loaded into 50 ton steel ore cars and transported to the smelter, where it is dropped into ore bins and one car lot in every eight or ten is recrushed and sampled to ascertain values. These bins are from 30 to 40 feet above the furnace charging floor. Charging cars moved by electric locomotives are filled with ore from these bins and with the proper quantity of coke are fed into the blast furnaces.

The melted slag and matte flow continuously from a water cooled spout into a settler, where the matte separates on account of its gravity and the slag flows into an extra settler and direct to the cast-iron slag-cars, by which it is conveyed to the dump. The matte is tapped from the bottom of the settler and still in a molten state, is poured into a converter, where it is blown to blister copper.

It will hence be noted, that the smelting process in the Boundary is exceedingly simple as compared with practice elsewhere, and by operating plants of large capacity and of strictly modern design, smelting is done at a very low cost.

Another favourable factor is the proximity of large coal areas, whence an abundant supply of excellent fuel is assured for smelting purposes. For power generation, however, coal is not extensively used either at the mines or smelter since all machinery is operated by electricity transmitted from a distance.

In brief, it may be stated that in the Boundary district, not only are the ore bodies unique, but the special conditions favourable to their utilization are also quite exceptional.

DISCUSSION.

Mr. HODGES.—By low-grade Boundary ores reference is here made to the low grade ores derived from the limited area in the vicinity of Phœnix, and from the Mother Lode and Oro Denoro mines which are situated only a few miles from Phœnix, in the Boundary District. These ores, concerning which I have prepared the above notes, cover, as I have already observed, a very limited area, and at the smelters now in operation they are smelted in the furnaces with the proper amount of coke. From 10,000,000 to 30,000,000 tons of these low-grade ores are in sight in the Boundary District, and to lay stress on the importance of these deposits is the main reason for the compilation of the above few notes.

I have remarked in my paper that we do not use flux, but this statement requires modification. In smelting from 3,000 to 4,000 tons of ore a day we use a little ore from outside mines as a flux, but it is a very small quantity—from 5 to 10 tons—and this is, moreover, a temporary expedient. We are further fortunate in being favoured with an ample supply of the best coking coal in the Northwest, which is obtained from a coal-field not very far from our mineral area.

THE PRESIDENT—Apart from the general interest of Mr. Hodges' paper those of us who had the pleasure of visiting his company's mines and smelting works the other day will be especially interested in the details with which he has supplied us. (Applause). I would be glad to hear remarks from gentlemen present upon the subjects which have been so ably brought before us.

Mr. Frecheville—To those of us who were privileged to go over the Granby Company's mines and smelting works, it is exceedingly interesting to hear Mr. Hodges' account of them and his summary of their operations. Having looked at the plans in the office of the company I would like to ask him about the deposits of ore which I understand exist off the main run. I saw upon the plan that there was a main belt which, I understand, consists of two beds that have been impregnated with ore. It appeared to me, however, that this belt is connected with some other body of ore, although I do not quite understand the exact relation which this deposit bears to the main belt of ore. Perhaps he will be good enough to tell us about them. Another point which struck me particularly, relates to the outcrop at that portion of the mine which we saw in the railway cutting just below the shaft house. We there saw an outcropping of ore as it had been in a state of nature; and one was particularly struck with the small amount of surface action when it is compared with the copper outcroppings that are found in other countries. For in other countries we are accustomed to find that oxides go down from the top; and we are also accustomed to find a good deal of oxidation in some countries, and particularly in dry countries like Chile and Queensland; while in the lead ores in other places the carbonates exceed the oxides, more so than in the higher sulphides of copper. But in the Granby mines, apparently, we do not see much indication of that kind. In the first place there is very little oxidation and no secondary enrichment. I came across an engineer who told me that he had sampled the Granby deposit in the early days, and could not get more than one-half per cent. of copper out of it. Our visit was most interesting. As a stranger one cannot but be impressed with the simplicity of the system which is in operation there. I am told that ore is taken from this mine, and that within 48 hours its product, which consists of 99 per cent. of copper, is shipped from the smelter. I dare say that this is literally true, and that this represents the result of the whole operations which make it effective. Now, this is a remarkable thing; it is to me quite a revelation, I may say, to learn that this result should be possible in a mine which is concerned in the smelting of ore.

This ore averages somewhere between $4 and $5 per ton as regards the total value of the gold, silver and copper combined.

and Mr. Hodges has told us of the various favourable conditions which render its profitable extraction, possible. I am of the opinion though, that he has not mentioned one matter, making this omission no doubt from motives of modesty, namely, that added to all the conditions which he has detailed there has existed the very requisite one, of having good men at the head of this great business.

Mr. J. OBALSKI—I may say that I was very much interested in learning what has been accomplished at this mine. I did not see how it could be achieved, but after I had had a talk with Mr. Hodges I understood the matter better; perceiving that although they are compelled to handle *low-grade ore* they possess among their officials *high-grade men* who knew how to make the undertaking a great success. (Applause).

Mr. HODGES—In respect of the surface of our deposit, I may say that in some places it is of about the same richness as is the case in the lower levels of the mine. I believe that you, Mr. Frecheville, inspected one of these places, which was not at all changed from its original character, while in the second ash bed, at least two veins of ore ran down from the surface, the easterly one having a considerable proportion of lime in it, and having, moreover, leached out a little. As a matter of fact, however, most of our surface ores are really poorer than those found at a lower depth.

We have in one of our mines 10,000,000 tons of good ore, whereas, I may say, that the ore for a distance of 50 feet down from the surface was rather poor; but that was shown in our first development work. But we had to handle ores of very low grade, while at the same time we were forced to treat a very large tonnage of them, and these ores were of the same character as that which you saw in the open-cut upon the day of your visit. We put in operation a steam shovel capable of handling from 700 to 800 tons of ore per day, and in that manner developed that portion of the mine very quickly; while by adding quite largely to the capacity of our furnaces we reduced the cost of smelting to such an extent that we were able to make a profit.

I may further state that anywhere from 40 to 50 feet underground, and clear down to the lowest levels, the ore in the mine, as ore, is very uniform, both in composition and quality. We have

mined out in one year say from 800,000 to 900,000 tons of ore, while this year we will mine at least an equal quantity. If the price of copper were always the same the result of the year's operations would not vary as much as fifteen cents per ton, while the whole of the main bed of ore will not vary more than two per cent. in silica, nor one per cent. in lime, nor even as much as one per cent. in sulphur. And where else in the world, gentlemen, will you find such an ore body as that, so uniform in composition and value, not only in silica, iron and lime, but also in gold, silver and copper?

Mr. Trewartha-James—I would like very much indeed to offer one or two observations on Mr. Hodges' able paper. It must have been extremely interesting for those who were able to go to the Granby to see these lively illustrations of what are called mass reactions. The real secret of the great success which has been achieved at the Granby, as has been very properly pointed out, lies in the fact that the workmen, the enormous plant and the masses of ore, have all been wonderfully well handled, and the results have been highly creditable to all who have been concerned in the development of this great industry.

May I ask one or two questions not in a critical spirit but partly at all events because others may probably be interested in the answers? With regard to the underground operations—what size rock drills are used? Do they use the air hammer drills, and if so to what extent? Also, will Mr. Hodges kindly supplement his answer by giving us some idea as to how the ore is drawn from the stopes, whether by gravity or by modern mechanical methods, as conveyers, etc.?

With regard to the second settler at the smelting works, if Mr. Hodges can reply without revealing any trade secret, I would like to know whether a second smaller settler is better than one large settler, having about the same capacity as the two smaller ones; also whether any difficulty is experienced in keeping the slag flowing, and in maintaining the heat in the second settler.

Referring to the low-grade of the ore, I quite appreciate the clever work by which the mining at present of such low-grade ore has been made profitable, while I may add that in my opinion the time is not far distant when ores of about the same value may be profitably treated in other sections of the country, owing to

the great advances and improvements that are being made. For instance, the famous deposit of ore which is found in the Britannia mines on Howe Sound, where the value of the ore approximates to the values which have been given in Mr. Hodges' paper, should soon be profitably realized, although it is not self-fluxing, but has the disadvantage of possessing something like 30 to 35 per cent. silica in excess.

Without in any way wishing to detract from the wonderful work which has been done at the Granby, which we are all pleased to admit, and of which we are all so proud (hear, hear), and without wishing to infringe in any way upon commercial matters, I would ask if a roughly approximate figure can be given in respect of the cost of smelting?

Mr. HODGES—In reply to the first question, I may say that underground we use ordinarily three and one quarter inch drills which are driven by compressed air, *i.e.*, they are driven by an air pressure of 80 or 90 pounds per square inch at the drill. We make use of a few hammer drills, which are usually employed only by timbermen.

Now, in reply to the question respecting the gravity system I may state that we use neither plates nor conveyers in the stopes or tunnels of the mines. All the work is done by driving large tunnels to the first, second, and third levels in the ore body of from 40 to 50 feet apart and putting in inclined raises to the stopes above and on both sides of the tunnels, afterwards meeting overhead, while the ore is rolled into the gravity chutes, our controlling power being electricity.

Big ore cars carry 10 tons, and the small cars 5 tons. The ore after it is brought out of the mine is immediately passed through the rock crusher, for we find it to be more economical to break the ore into smaller sizes; after which it is taken to the smelter, while every time it is handled a few extra cents are added to the operating costs.

The ore is taken to the crusher when it leaves the mine workings, while from the crusher it passes along the conveyer belt, which is 42 inches wide with about 241 feet centres. This belt conveys the crushed rock from the crusher to the storage bins, from which it is loaded into railway 50-ton cars for hauling to the smelter.

I may add that we have one of the largest belts to be found in any of the mines you, gentlemen, have seen in the course of your trip. It has been in use a year or two, and has proved very satisfactory. Belts are, in my opinion, a great deal better than elevators, for on a belt there is ample room to place the ore, while you are not compelled to raise it too high. And, besides, in the case of elevators the wear and tear is very excessive, which is especially true when you use one of large capacity.

Answering the question of whether one large settler is better than two separate and smaller settlers which would allow the slag to flow the same number of feet, we think that the flow of slag should be stopped and the matte allowed to settle. Where we count upon catching most matte is in the first settler and less in the second, and still less in a third settler if we had one. The saving effected through the use of additional settlers is scarcely a commercial consideration. With the use of two settlers the case is somewhat different, as in this manner it is found that a considerable economy results. As a matter of fact we were the first in the Boundary country to use two settlers, as the ordinary custom had previously been to make use of only one, with a large pot to catch anything that should run over.

I do not think I can make any statements on the question of cost of treatment; for the result of treating our ores, which are worth from $4 to $6 per ton, depends of course upon the price of copper; still we think we are facing a very bad time if we are not making a profit of $1 per ton. (Applause).

Mr. Frecheville—I would like to make a remark with reference to the absence of gossan in the Boundary country which, I think is a remarkable fact, for we do not usually get ore without gossan. It is also a rather remarkable circumstance that practically no gossan, or at all events not enough of it to be at all significant is to be found elsewhere in British Columbia, although this is not at all the case in other mining countries. For my own part I attribute this peculiarity to the moistness of the climate, which prevents the ore from becoming oxidized as is the case in other regions. For the copper pyrites as it appears on the surface is quite fresh and even has moss over it.

Mr. R. W. Brock—The exposed surface of the ore bodies in British Columbia through glacial action, might account, in some

measure at least, for the absence of gossan; and I might say, while I am on this point, that the character of the ore depends to some extent upon the experiences through which the ore bodies have passed.

A little to the west of the Mother Lode mine the same ore deposit is found, or at all events, ore of a somewhat similar character, where for a distance of 60 feet or more upon the surface we find the usual accretion of weathered products and oxidized copper minerals, as well as native copper, etc.

Mr. E. COSTE—Might I enquire what is the price of coke used for smelting work upon Vancouver Island. This is an important item in connection of the treatment of the ore bodies which appear to exist here in such large quantities.

Mr. SUTTON—I expect this query is intended for me, although I am only in the employ of the Wellington Colliery Company as a geologist. This company supplies coke at from $5 to $5.50 per ton. I cannot give the figures positively, but I know they are in that neighbourhood. In large quantities it can possibly be obtained for $5 per ton, although I would not like to vouch for this.

A MEMBER—How is it then that the price of coal is $7.50 a ton in Vancouver?

A VOICE—Because they have no natural sources of supply.

Mr. TREWARTHA JAMES—No, no; it actually happens in our case that coke is cheaper than coal. Nevertheless coke is often practically unobtainable, because there is such a pressure upon coal production at the collieries of this Island, and coal production here is so profitable, that unless as in the case of an old standing contract like ours, no coke is for sale at all; although as far as the smelting industry is concerned, no doubt enough coke to meet any reasonable demand could be obtained at about the price Mr. Sutton has mentioned. The coal industry itself is an enormous one, and is, moreover, capable of enormous extension, for any reasonable quantity of coal is to be found upon this Island and a large proportion of it can be used for making coke, especially as we now know that coal which is *prima facie* not suitable for the ordinary purpose of coke-making can, by a certain process of working, now be used for that purpose. The low price of coke is

due, in part at all events, to the fact that when the contract referred to was made the people one and all were very anxious to found on this Island a smelting industry and to place it in a strong position; moreover, at that time when this price was arranged the demand for coal was not as great as it is now.

A Member—Do you pay $5 a ton for it.

Mr. Trewartha-James—No doubt if we were arranging to buy to-day the price would be set at about $6 per ton. It is very desirable that the arrangements for supply should be increased.

Mr. Wm. Blakemore—I would like to remind the members of the Institute that the production of coke on Vancouver Island is very inconsiderable for the reason given by Mr. Trewartha-James, and that the rate of $5 a ton at the ovens would give coke to any smelter on the Island at about the same price as the Granby Company has to pay for coke in the Boundary country, so that in that district they are not in this connection handicapped to any greater extent than we are here.

Mr. H. Carmichael—Another feature which greatly favours a smelting industry on the southern British Columbia coast is the unique and immense inland water ways which we possess, affording the cheapest water transportation of ores and fluxes.

From Skagway to the southern end of Vancouver Island there is a continuous water way of roughly 1,000 miles open only to the ocean at two short stretches, the longest of which can be crossed in three hours.

Leading off from this main water way are a large number of inlets, many of them penetrating 100 miles into the heart of the country; these inlets together with innumerable islands make up a coast-line many thousand miles in length.

For instance, the length of Vancouver Island is 350 miles, while the coast line of the western shore, exclusive of islands, is 1,300 miles.

There are also on the Coast many available and easily harnessed water powers, some of them capable of developing over 30,000 horse power.

The mineral prospects look brighter this year, I believe, than they have done for some time; reliable reports of good ore bodies are being brought in from the Portland Canal camp and from Queen Charlotte Islands.

From Valdez Island we have news of a recent strike of a copper ore carrying associated gold tellurides running half an ounce of gold per ton—there are also a number of prospects where development work is showing up good ore.

I think we can safely look forward to a larger ore production on the Coast than we have had for the last five or six years.

MINERAL RESOURCES OF THE "LARDEAU," BRITISH COLUMBIA.

By NEWTON W. EMMENS, Trout Lake, B.C.

Annual Meeting, Montreal, March, 1909.

What is popularly known in British Columbia as the "Lardeau," is a strip of country bounded by the divide between Fish river and Isaac creek on the northwest, Cascade creek on the southeast, the divide between the Lardeau and Duncan rivers on the northeast and the divide between Trout lake and the Lardeau river, and the Arrow lakes on the southwest. In reality this section consists of the mining divisions of "Lardeau" and of "Trout Lake," in the West Kootenay District of British Columbia as shown on the accompanying map. In these Divisions occur three recognised mineral belts, namely, the Lime Dike, the Central, and the Southwestern. Of these, the Central is the most important, as the ore showings are more extensive and, in consequence of better transportation facilities, more prospecting and development work has been done here than on the others, although on these are also several promising prospects.

It is not the purpose of this paper to enter into a scientific discussion in respect of the geology and mineral occurrences in these belts; but rather to treat the subject from an economic standpoint, since the existence of large bodies of gold, silver, lead and zinc ores is known, and these sooner or later will become of commercial importance.

The writer is personally familar with the greater portion of the "Lardeau," from Menhinick creek to Cascade creek and from the head of the North Fork of Lardo creek to the head of Canyon creek. This district includes one of the most rugged and picturesque areas in the Selkirk mountains, the higher peaks of which, rising to heights of 7,000 to 9,000 feet above sea level are crowned by glaciers and fields of perpetual snow. The mountain-sides are steep, in many places precipitous, with deep narrow valleys

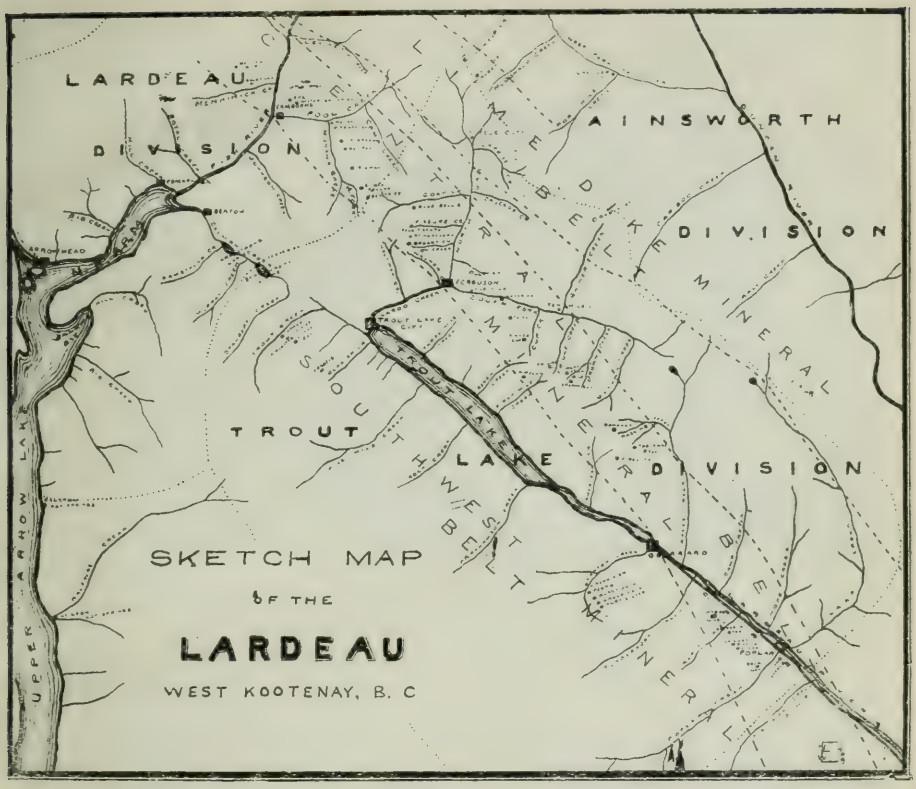
between, and are densely timbered with cedar, spruce, hemlock, fir, and balsam to elevations of from 5,500 to 6,000 feet above sea level. The underbrush, to elevations of 5,000 feet, is dense, making transportation and travelling away from the roads and trails arduous. Above the timber line the mountains are clothed with grasses and alpine varieties of flowers, some of which are very beautiful; but occasionally the hillsides at this altitude are capped with glaciers and snow fields, or the soil has denuded away leaving the bare rock. Along the valleys flow streams of water, which owing to the steep gradient of their beds, afford splendid water powers.

Meanwhile, for the sake of clearness and to avoid needless repetition, it is proposed to describe the three mineral belts separately.

CENTRAL MINERAL BELT.

The rocks along this belt are largely of sedimentary origin, much altered in places by metamorphism, and having a general north-westerly strike and north-easterly dip. From north of Fish river to south of Cascade creek bands of slate, schist, and phyllite extend, cut and intruded by bands and dykes of a yellow-weathering, blue-green rock of eruptive origin. This rock Mr. R. W. Brock, Director of the Geological Survey of Canada, designates a "diabase schist." This diabase schist occurs all along the mineral zone and at the southern end of the belt is itself heavily impregnated with pyrite and is sometimes gold-bearing, especially in the neighbourhood of the gold-quartz veins. In many places along the northern portion of the district, the slates and phyllites adjacent to the ore bodies are carbonaceous to such an extent as to blacken everything with which they come in contact. Locally they are called "graphite." In the neighbourhood of the Nettie L., Silver Cup mines, and southward in the Cromwell basin, are bands of quartzite. Many of the vein-outcrops, where exposed above the timber-line or along water courses, are traceable for long distances, sometimes standing out above the softer enclosing rocks like stone fences.

On the Nelson group, situated between Menhinick and Sable creeks on the west side of Fish river, a quartz vein has been opened up by surface trenching, and a short cross-cut, showing the vein to be twenty feet wide, with well defined walls. In one of the open



cuts native gold can be easily seen in the quartz outcrop. The foot-wall portion of the vein, in the cross-cut, assays 0·2 ounces gold and 0·6 ounces silver, over a width of twelve feet, and the hanging-wall portion, over a width of eight feet, assays 0·15 ounces gold and 0·3 ounces silver. This vein has been traced for several hundred feet along its strike by means of the open cuts above referred to and crosses the formation at a slight angle in both dip and strike.

The Gold Finch, situated on the north side of Menhinick creek, 3,200 feet above sea level, contains a number of quartz veins and stringers in phyllite. Some of these stringers were rich in native gold producing some splendid specimens, while the country rock between them also carried appreciable quantities of that metal. Considerable exploratory work has been done, but owing to the irregularity of the veins, the loss of equipment

through forest fires, and the lack of adequate working capital, nothing definite has been accomplished to determine the real value of the property.

At the Eva mine, situated on the south side of Fish river, at an elevation of 3,400 feet above sea level, near the town of Camborne, the formation is phyllite and schist cut by two fault planes having a south-easterly strike and dipping away from each other at an angle of eight degrees. The two main veins, consisting of quartz, occupy these fault planes and are connected by a series of cross veins extending from one to the other, but, which, so far as observed, do not extend out into the wall rocks beyond them. The mineral content of the veins consists of pyrite, galena, zinc-blende, and native gold, and the rock between these veins and stringers carries sufficient gold, in many places, to pay for mining and milling. These veins have been extensively developed by means of drifts, cross-cuts, and raises, proving not only their continuity but the presence of large bodies of pay-ore to the lowest depths attained. This mine is the most thoroughly developed and equipped in the neighbourhood of Fish river, its ten-stamp mill having been operated at a profit for some years. The mine is now idle pending the completion of arrangements for increased milling capacity, which the mine development fully warrants.

Adjoining the Eva on the south-east, at an elevation of 3,600 feet above sea level, is the Oyster-Criterion. The Criterion vein, on which most of the work has been done, is from five to fifteen feet wide, partly fissure filling, and partly replacement of the enclosing phyllites. The gold occurs in both the quartz and around the unaltered phyllite inclusions. In the Criterion drift a galena vein was found, five feet wide, lying in a fault plane with gouge and slickensided walls. This galena vein was followed and found to cut through the Criterion vein, faulting it fifteen feet. Further on an east and west fault completely cuts off the galena vein.

The property is equipped with a ten-stamp mill, concentrators, air compressor, tram, etc., but is now idle owing to litigation, which although now settled, left the owners without sufficient working capital to re-open the mine. No figures are available as to the yield of the ore treated in the mill, but the returns are said to have been satisfactory.

Continuing in a south-easterly direction the next group on which any considerable work has been done is the Silver Dollar.

FIG. 1—View looking north-west from the Copper Dollar Claim.
A. Goldfinch Mine. B. Tram. C. Mill. D. Fish River.

FIG. 2—View looking south-east from Goldfinch Mine.
A. Eva Mine. B. Oyster-Criterion Mine. C. Eva Tram.

Between it and the Oyster-Criterion lie the Mohawk, Homestake, Colorado, Del Rey, and Gilman groups. On all of these claims there are promising gold-quartz veins ranging from one to ten feet in width, but which have only been developed to a limited extent, the owners being prospectors of small means. The showings are good and warrant development, more especially as the natural advantages in the matter of timber, water-power, and mining facilities are such that low grade ore can be made to yield satisfactory profits.

The Silver Dollar is situated near the head of the north fork of Mohawk creek, at an elevation of 6,100 feet above sea level. The main vein is quartz, having a north-westerly course and cutting the enclosing rocks in both strike and dip. Its width varies from a few inches to thirty feet and its mineral contents consist of pyrite, galena, zinc-blende and native gold, with occasionally a little gray copper. The quartz assays from 0·05 ounces gold and 0·54 ounces silver to 0·4 ounces gold and 1·35 ounces silver per ton. Between the quartz and the foot-wall is a streak of steel-galena from four inches to two feet wide, assaying 28·25 ounces silver and 24·83% lead. In an open cut on the vein, south-east of the workings, is a streak between the vein and the foot-wall of cubical galena two feet wide. This ore assays 0·2 ounces gold, 64·45 ounces silver and 24·82% lead. In other open cuts and prospect pits along the vein outcrop good ore was found, some of it showing native gold. Associated with the galena is more or less zinc-blende, a picked sample of which assayed 0·1 ounce gold, 1·55 ounces silver and 34·5% zinc. About a thousand feet of development work has been done on the property, but the workings are all at a comparative shallow depth below the surface (under 150 feet) so that the character and tenor of the ore at depth, still remains to be determined.

Half a mile south-east and at eight hundred feet greater elevation than the Silver Dollar, on the divide between Mohawk and Goat creeks, is the Beatrice mine. There are two known veins traversing this property in a south-easterly direction. One is from two to five feet wide carrying fine-grained galena, zinc-blende, pyrite, and gray copper assaying 0·25 ounces gold 120·72 ounces silver and 17·42% lead (zinc not determined). This vein has been opened by two cross-cuts driven at different levels and

by drifts and raises. In doing this work some three hundred tons of the higher grade ore was sorted out and shipped to the smelter, the balance being thrown on the dump for future treatment. The vein is much twisted and contorted along its strike by lateral pressure, but no faults have so far been encountered.

The second vein, called the "gold lode," lies to the west of the galena vein. Where opened by surface cuts it is from four to six feet wide mineralized with pyrite and a sprinkling of galena, and assaying 0·15 ounces gold and 0·95 ounces silver to the ton. Insufficient work has been done on this lode to determine either its extent or value.

Crossing Goat creek there are no known veins of any importance until the True Fissure property is reached, with the exception of a quartz outcrop on the Blue Bell No. 2, which adjoins the former property on the north-west. The outcrop of this vein is very prominent, standing out in the form of a bluff some sixty feet in height, and traceable for a distance of several hundred feet. This vein is gold bearing but sufficient work has not been done to determine its commercial value.

The True Fissure property is situated on the Great Northern mountain at the head of Fissure creek, on the west side of the North Fork of Lardo creek, at an elevation of 6,000 feet above sea level. There are two veins on the property known as the St. Elmo and True Fissure respectively. The St. Elmo vein has a course of N. 77° W. with a north-easterly dip cutting the formation obliquely in both directions. In width it is irregular, varying from two to six feet. It has been opened by an adit on its course one hundred and fifty feet long, and by raises and winzes. The ore is galena, pyrite, zinc-blende, and gray copper, carrying gold and silver, with a quartz gangue. Much of this ore is sufficiently rich to be shipped direct to the smelter without previous treatment. During the past ten months, two hundred and ten tons of the ore was shipped, giving average returns of 0·11 ounces gold, 81·3 ounces silver, 20·5% lead and 8·2% zinc per ton. Selected samples of cubical galena from this vein assay 54·5 ounces silver and 70·2% lead, while selected samples of gray copper from the same place assay 515 ounces silver and 10·37% copper. In sorting this ore for shipment care was taken to keep it as free as possible from zinc-blende, zinc being penalized by the smelters to the extent of fifty cents per unit

FIG. 3—Part of the ore exposure on the True Fissure

FIG. 4—Broadview Hill from the north-west.
A. Broadview Shaft. B. No. 3 Level. C. Nettie L. Mine.
D. Silver Cup Mine.

in excess of eight per cent. There is, in consequence, a considerable accumulation of ore on the dump assaying 0·04 ounces gold, 72 ounces silver, 39% lead and 32% zinc per ton, for which at present there is no market.

The True Fissure lode is a big quartz vein having a course of S. 55° E. with a north-easterly dip. It lies along the eastern slope of an ancient glacial basin between two spurs of the mountain, dipping with the slope. The overlying rocks have been eroded away by the ice, and atmospheric agencies, exposing the vein over an area of 500 by 1,000 feet. Much of the ore thus exposed consists of a fine-grained galena assaying 0·06 gold, 11·44 ounces silver, 6·4% lead; and a fine-grain pyrite assaying 0·3 ounces gold and 10·5 ounces silver. A short distance beyond the north-west edge of this exposure, the vein shows in the bed of a small creek. Here is found some coarse-grain galena assaying 0·12 ounces gold, 44·68 ounces silver and 22·3% lead per ton. Below this and a few feet to the south some cubical-galena, and coarse-grain pyrite, carrying gray copper, was found and developed by a surface cut along the strike of the vein. The cubical-galena assayed 68·8 ounces silver and 68·5% lead per ton, while the gray-copper-bearing pyrite assayed 0·1 ounce gold, 92 ounces silver and 0·7% copper per ton. About ten tons of ore was shipped from this cut. One hundred and sixty feet north-west from this cut the vein has been explored by the Blue Bell cross-cut and drifts in both directions therefrom on the course of the vein. Where the cross-cut intersects the vein it proved to be nineteen feet wide between walls, assaying as follows, commencing at the hanging-wall. First six feet, 0·2 ounces gold, 1·9 ounces silver; second six feet, 0·25 ounces gold, 7·05 ounces silver; and last seven feet, 0·05 ounces gold and no silver per ton. In the south drift from the cross-cut a streak of galena lying between the vein and the hanging-wall was found, assaying 0·05 ounces gold, 32·25 ounces silver, 38·7% lead and 7·3% zinc, per ton, the vein itself being good concentrating ore. In the drift north of the cross-cut two shoots of galena ore have been opened up, one by an underhand stope, and the other by a raise. The first ore-shoot carries galena, zinc-blende, pyrite, gray-copper, and chalcopyrite. Selected samples of the galena from this shoot assay 76·25 ounces silver and 75·5% lead, selected samples of the gray copper and

pyrite assay: 1 ounce gold, 694·2 ounces silver and 3·78% copper, while selected samples of the zinc-blende and chalcopyrite assay: 0·375 ounces gold, 22·12 ounces silver, 45·1% zinc and 1·54% copper to the ton. Thirty tons of ore shipped from this point gave returns of 0·15 ounces gold, 48 ounces silver, 39% lead and 8·7% zinc per ton. The second ore-shoot consists of galena, pyrite, gray-copper and zinc-blende, averaging 0·15 ounces gold, 40 ounces silver, 5·4% zinc, 26% lead and 1% copper, per ton.

Twelve hundred and fifty feet south-east of the Blue Bell cross-cut the True Fissure vein is again explored by a cross-cut. Here it is twenty-six feet wide between walls assaying as follows, commencing from the hanging-wall: First six feet, 0·09 ounces gold, 3 ounces silver; second six feet, 0·1 ounce gold, 19 ounces silver, 2·5% lead; third six feet, 0·3 gold, 9 ounces silver, 5% lead, 10% zinc; last eight feet, 0·3 ounces gold and 0·7 ounces silver per ton. In addition to the workings enumerated, there are a number of open cuts and prospect pits on the vein at various places, all of which show ore of a similar character and tenor.

Adjoining the True Fissure on the south-east is the Great Northern group, situated at an elevation of 6,100 feet. The vein on this property is locally believed to be the continuation of the True Fissure. This assumption is, however, questioned by the writer, since there are indications of a fault which throws the true fissure vein several hundred feet to the eastward, and the Great Northern lode is believed to be a parallel vein. Where opened by a cross-cut, it is three feet wide, lying in badly crushed, black carbonaceous phyllite, showing strong evidence of movement. It has a south-easterly strike with a flat dip to the north-east. The ore consists of pyrite, galena, zinc-blende and gray copper, assaying 0·1 ounce gold, 30·5 ounces silver, 4% lead and 1% copper (zinc not determined). There has been so little work done on the property that the economic importance of this vein has not been fully demonstrated.

The next group south-east, is the Broadview lying on the Broadview hill, a spur of the Great Northern mountain, at an elevation of 6,000 feet. On this property is the extension of the True Fissure lode (here called the Broadview vein) marked by a long and prominent outcrop, and a small parallel vein carrying copper.

The Broadview vein has a course of S. 45° E. and a north-easterly dip. It is opened by two shafts, one a hundred and twenty

feet deep, and the other twenty feet deep. These shafts are two hundred feet apart and are sunk on the apex of the vein where it crosses the summit of the hill. Three hundred feet vertically below and eleven hundred feet north-west of the hundred and twenty foot shaft, an adit (No. 3 level) has been driven in on the vein for a distance of seven hundred feet; and four hundred and eighty feet north, and again one hundred and forty feet vertically below this, another adit (No. 4 level) has been started to develop the vein. This adit is a cross-cut from the hanging-wall side, but has not yet reached the vein, having still to be continued some thirty feet. In sinking the hundred and twenty foot shaft a galena ore-shoot was found pitching 45° to the north-west in the vein. This shoot has been developed by a drift from the sixty foot level and a stope thence to surface. The ore consists of galena, zinc-blende, pyrite, and chalcopyrite. Two hundred and thirty-four tons of ore were shipped from this shoot and averaged 0·09 ounces gold, 35·19 ounces silver, 34·2% lead and 1·6% copper to the ton. The ore was all hoisted by hand, which, proving too expensive, for the grade of ore obtained, required the suspension of work at this point pending the cutting of the shoot in the No. 3 level. On the hanging-wall side of this galena is a band of cellular quartz assaying 0·2 ounces gold and 4·5 ounces silver per ton, the thickness of which has not yet been determined. On the foot-wall side is pyrite, zinc-blende and chalcopyrite. On the dump at this shaft there is twelve hundred tons of ore, all of which will pay to mill, but is too low grade to ship direct to the smelter without concentration. From the bottom of the twenty-foot shaft, a drift has been driven for a distance of forty feet on the vein in a north-westerly direction. The vein here is four feet wide carrying pyrite, chalcopyrite, galena, zinc-blende and, in places, gray copper. The foot-wall portion of two feet averages 0·15 ounces gold, 6 ounces silver, 4% copper and 43·9% iron; the hanging-wall portion of two feet averages 0·15 ounces gold and 1·85 ounces silver; while samples containing gray copper assay 0·2 ounces gold, 105·2 ounces silver, and 3·7% copper to the ton. On the No. 3 level the vein has been cross-cut in six places and by a raise to surface, a distance of one hundred and seventy-five feet. In these workings the vein is from three to twenty-one feet wide, of a banded structure, carrying pyrite, galena, zinc-blende, and chalcopyrite, with a sprinkling of gray copper, in a gangue of

quartz and feldspar. Between these bands occur streaks of fine grain galena and pyrite. In the No. 1 cross-cut, the vein has a width of sixteen feet, assaying from 0·14 ounces gold and 3 ounces silver to 0·72 ounces gold and 2·4 ounces silver per ton, exclusive of the pyrite-galena streaks; these latter assay from 0·2 ounces gold, 8 ounces silver, 7·5% lead and 2·4% copper to 0·54 ounces gold, 16 ounces silver and 5·5% lead to the ton and are from four inches to two feet wide. Near the No. 6 cross-cut on this level lying between the vein and the foot-wall is a streak of gray copper from two to four inches wide, assaying 0·25 ounces gold, 495. ounces silver, and 7% copper. No development work has been done on this streak, although it is well worth exploring, as it is likely to lead to a good shoot of this class of ore.

The copper vein has a course of S. 35° E. with a slight dip to the north-east; in width it is irregular, ranging from a few inches to two feet. It has been developed by an adit driven on its course for a distance of two hundred and twenty feet. A trial shipment of twenty tons of the ore gave returns of 0·12 ounces gold, 6·2 ounces silver and 5·7% copper; while selected samples assay, 0·2 ounces gold, 19·04 ounces silver and 24·25% copper. This copper vein should make a junction with the Broadview lode between the portal of the No. 3 level and the place where the new, No. 4 level, will intersect it.

The Nettie L. is situated on a spur of Ferguson mountain on the east side of the North Fork of Lardo creek at an elevation of 5,100 feet above sea level. Development work has been confined to opening three veins known as the Main lode, Cross lode and Big Quartz lode, respectively. The Big Quartz lode has a south-easterly strike cutting the formation, while the Main lode follows closely the strike of the enclosing rocks but cuts them in dip. The junction of these two veins has been found in the lower workings of the mine, which are three hundred feet vertically below the outcrop. From these veins stringers of quartz and ore run off into the wall rocks, which are carbonaceous and much broken and disturbed by folding and slips. The ore consists of pyrite, galena, zinc-blende, chalcopyrite and gray copper, in a gangue of quartz carrying calcite and siderite. It occurs not only as fissure filling but also as a replacement of the containing rocks. Altogether some 6,000 feet of cross-cuts, drifts, raises and shafts have been

made and about three thousand tons of ore have been shipped to the smelter, part of which yielded 0·16 ounces gold, 12·1 ounces silver, 17% lead and part 0·13 ounces gold, 149·6 ounces silver, and 26·9% lead per ton. In this mine occurs some light-brown zinc-blende rich in gold; some of it containing as much as 10 ounces of that metal to the ton. Owing to the expensive wagon haul from the mine to Trout lake, the railway terminus, only the first-class ore has been shipped, the balance being stored on the dumps. In 1903, a mill was built at Five Mile, on the south fork of Lardo creek, one mile above its junction with the north fork, for the purpose of treating the second class ores from this mine and that of the Silver Cup, to which further reference will be made later. Briefly, the process consisted, in wet crushing, water concentration, drying, roasting with the addition of salt, mercury amalgamation, and retorting the resultant amalgam. Some 10,000 tons of ore were treated in this mill but the process proved unsatisfactory and the plant was closed. The process, as outlined, is clearly not suited to the treatment of ore containing gray copper rich in silver, as the bulk of that mineral would be slimed and carried off in the water. The writer is informed that not only did this occur, but that a considerable quantity of mercury and amalgam also escaped with the tailings. This mill is another monument to stupidity, whereby it was attempted to make the ore suit the reduction process, instead of the process suit the ore. Unfortunately there are many like monuments to be found in the various mining districts of the world.

South-east of the Nettie L., the Silver Cup is the next mine of importance, although there are some promising prospects between, of which the Yuill and Canadian groups, are chiefly worthy of mention.

The Silver Cup mine is situated on Silver Cup mountain, on the south side of the south fork of Lardo creek at an elevation of 6,500 feet above sea level. It is by far the best developed and most important mine in the Lardeau and is at present shipping from one hundred to one hundred and fifty tons a month to the Trail smelter. On this property are two lodes striking almost parallel to the formation, the more northerly being called the Silver Cup vein and the more southerly, the Blind vein since it does not outcrop at the surface. Between these veins are several

cross-fissures in one of which was found a big ore-body. The ore occurs as lenticular masses both in strike and dip, sometimes near one wall and sometimes near the other, and often attain considerable size. Their mineral contents are, galena, zinc-blende, pyrite, and gray copper. The mine has been developed to a depth of over 1,000 feet below the vein outcrop and some of the richest gray copper ore comes from the lowest workings, proving that this mineral is not due to surface alteration and enrichment but comes from a deep-seated source. Only the first grade ore is shipped, running in the neighbourhood of 0·6 ounces gold, 200 ounces silver and 30% lead. The second grade ore, of which there is a large quantity, is stored on the dumps awaiting some process to treat it. This ore will average about 0·4 ounces gold and 60 ounces silver in addition to the lead, zinc and copper contents.

The Triune mine is situated a short distance south-east of the Silver Cup on the north slope of the mountain-spur dividing Triune and Brown creeks, at an elevation of 7,800 feet above sea level. The main vein is of quartz, from four to eight feet wide, and has a south-easterly strike. South of this is another parallel vein. The ore occurs as shoots in the vein and is similar to that of the Silver Cup, although not so high in grade. The upper workings on the vein are close under a glacier, which occupies the basin at the head of Triune creek. As a consequence the temperature never rises above freezing point, and even in mid-summer the ground remains frozen and the walls of the workings are covered with frost crystals, and if the levels are not in use for any length of time they fill up with ice. In winter, because of snow-slides, it is not practical to operate the mine as there is no ground in the Triune basin where a permanent camp can be built, which would be free from danger from this source.

On the other side of the ridge from the Triune are the I. X. L. and Morning Star, situated on the north side of Brown creek near its source, at an elevation of 7,000 feet above sea level. On these properties are several veins, one of which is the extension of the Triune, and another is thought to be the extension of the Silver Cup vein. The veins vary from eighteen inches to three feet in width, but little development work has been done of a definite character. Good assays have been obtained from selected samples. one of azurite in quartz with pyrite gave 2·2 ounces gold, 713·8 ounces silver and 5·8% copper.

The next property south-east is the Cromwell group, situated on the south side of Brown creek, near its source, at an elevation of 7,400 feet above sea level and above the timber line. The Cromwell vein is quartz and is from two to four feet wide, occupying a fissure with smooth walls. The development consists of a few open cuts and a drift on the course of the vein seventy feet long. The mineral contents are, pyrite and chalcopyrite with a sprinkling of galena, much oxidized near the surface but changing to unaltered sulphides within a few feet. For the first thirty-five feet of the drift the ore averages 1·16 ounces gold and 1·15 ounces silver, while selected samples of the oxidized ore assay 7·92 ounces gold, 15·2 ounces silver and 0·49% copper. For the next twenty feet it rapidly decreases in value, but improves near the face, indicating the approach of another ore-shoot. A trial shipment of eleven tons sent to the smelter yielded 5·33 ounces gold and 5·64 ounces silver to the ton.

Near the summit of the ridge on the north-east side of Trout lake, about a mile north-west of the head of Eight Mile creek is the Winslow. The vein here is of quartz striking north-west, cutting the formation, and carrying pyrite, galena and native gold in small quantities. It is developed by a cross-cut to, and drift on the lode, and by open cuts at surface. The vein is eight feet wide carrying from 0·4 ounces to 0·6 ounces gold per ton. The property is now under bond and is being developed in a systematic manner with encouraging results. There are several other meritorious claims in this immediate vicinity carrying a similar class of ore, awaiting the necessary capital for their development.

Continuing south-east from the Cromwell, the next ore exposure of any importance is on the Bonanza, situated at the head of the middle fork of Haskins creek at an elevation of 6,800 feet above sea level. The vein here is from one to three feet wide, heavily mineralised with pyrite and a sprinkling of galena. It lies in a carbonaceous phyllite conforming to the strike and dip. The development consists of an adit on the vein one hundred and sixty feet long and several open cuts. The ore assays from 0·2 to 1·8 ounces gold and 1·5 to 6 ounces silver to the ton.

At the head of the south fork of Haskins creek, on the south side of the basin, at an elevation of 7,600 feet above sea level, is the Kootenay Bell property. The vein here has an easterly strike

and southerly dip cutting the formation. It is exposed in the cliffs on either side of the basin and has been opened by an adit driven on it from the south slope of the hill, on the south side of the basin. Here it is six feet wide and well mineralised with pyrite and galena. The property is above the timber line and there is no water near the present workings, which are situated on a very steep hill-side, making it difficult of access.

On a spur of the ridge on the north-east side of Trout lake, about half a mile south of American creek and three miles north-east of the town of Gerrard, at an elevation of 6,800 feet above sea level, is the Fidelity group. Here are two veins, one a quartz lode five to eight feet wide and the other a galena vein varying in width from a few inches to four feet. This latter vein is composed of quartz carrying pyrite, and galena with a solid streak of the latter lying between it and the hanging-wall. This is steel-galena, having a beautiful silky texture and carrying silver. It has been developed by a drift and open cuts. In the drift the vein lies very flat, almost a blanket, but straightens up near the face. No assays of this ore are available. The property is well located for economic mining and is worthy of further development.

The Central Mineral Belt extends down to the level of Trout lake close to its south-eastern extremity, near Gerrard, and crosses the Lardeau river near to the mouth of Tenderfoot creek. While there are several prospects between the Fidelity group and Tenderfoot creek, very little development work has been undertaken with the exception of that on the Mobb's mine.

The Mobb's mine is situated on the west side of the Lardeau river, half a mile north-west of Rapid creek at an elevation of 2,720 feet above sea level. It is most favourably situated for economic mining, being only three-quarters of a mile distant from and 600 feet above the railway. There are two systems of veins traversing the property, one following closely the strike of the enclosing rocks and the other cutting them at various angles. The "G" vein belonging to the first system is an irregular deposit formed by replacement along a fracture zone. It consists of pyrite and galena in a gangue of quartz, assaying 7 ounces silver and 4·2% lead; selected ore from this vein assays 95 ounces silver and 77·5% lead. Of the veins belonging to the second system, the following are the most important: No. 1, east, is a quartz

vein from two to four feet wide cutting the formation at almost right angles with a very slight easterly dip, and is separated from both walls by a thin gouge and is slickensided in places. Its mineral contents are pyrite, galena and native gold, averaging in value 0·3 ounces gold and 2·5 ounces silver per ton. Development is being undertaken by means of an adit driven on its course.

The No. 1 west vein occupies a fault plane two hundred and seventy feet west of the No. 1 east. It crosses the strike of the formation at right angles and has a vertical dip. The quartz is from eighteen inches to five feet in width, has a banded structure, and is mineralized with pyrite, patches of galena, and native gold, averaging 0·35 ounces gold per ton. This vein is being developed on its course by an adit, which has now reached a distance of one hundred and fifty feet from the portal. At eighty-nine feet it cuts through a small vein conforming to the formation, and at one hundred and forty feet cuts another vein, on the west side of the drift, but whose eastern extension has not yet been found. The first of these veins is small and irregular, but assays well in gold while the second is eighteen inches wide, cuts the formation in dip, and assays 1·5 ounces gold per ton, some of which is quite coarse. Two hundred feet further west is the No. 2 west vein, cutting the formation in a southerly direction and having a dip to the west. It has been drifted on for a distance of a hundred feet and is from two to four feet wide, assaying from 0·25 ounces to 2 ounces gold per ton. This vein is striking at an angle toward No. 1 west. Their junction will be cut by the drift now being driven on the latter, at a depth of sixty feet vertically below the drift on No. 2 west. Still further west are two other veins cutting the formation in a south-westerly direction. These are quartz of a banded structure, from four to six feet wide carrying pyrite, galena, and native gold. These will be developed later.

Adjoining the Mobb's mine on the south-east is the North Star group having a similar system of veins. On this property some arsenopyrite has been found rich in gold, occurring as small stringers in the diabase schist as well as in the vein-quartz. Only a limited amount of development work has been done on this property and no assays are available, but it is stated that the average gold and silver contents of the ore is about the same as those at the Mobb's mine.

Between Rapid and Poplar creeks are several properties on which some surface prospecting has been done and short adits driven, but on none of them has there been sufficient development to determine their value, as mines. Among the most promising may be mentioned the Calumet and Hecla, the Hanson, and the Gold Park. On all these properties numerous veins occur, some of which have yielded rich specimens of native gold, both in quartz and in arsenopyrite, while from the Hanson property some magnificent specimens of native gold imbedded in solid galena have been obtained. Some twelve hundred pounds of this gold-galena ore were shipped to the smelter.

On the south side of Poplar creek, close to the railway, is situated the Lucky Jack property. The main lode outcrops on a steep hill-side only a short distance from the track. It is quite prominent and stands out from the enclosing rocks like a wall. The vein is quartz carrying, pyrite, galena and arsenopyrite, with native gold in bunches, fibres and plates. It cuts the formation in strike and has a vertical dip. The gold occurs, not only associated with the sulphides but also in the quartz. It is, however, very pockety and the ore between the pockets is lean. The development work consists of a short adit driven on the vein where the first gold discovery was made, another adit about sixty feet lower down the hill and a shaft connecting the two. There are a number of other veins on the property, but they remain practically undeveloped. Some of them are said to yield fine native gold specimens, as well as arsenopyrite rich in gold.

Immediately adjoining the Lucky Jack on the west, is the Swede group, situated at an elevation of 3,600 feet above sea level. On this property are several veins running with, and crossing the formation as on the other properties in this portion of the mineral belt. They are of quartz carrying, pyrite, galena, arsenopyrite, and native gold, varying in width from a few inches to six feet. In several places these veins occur at close intervals and, at surface, the decomposed rock (diabase schist) lying between them yields gold, by panning. In other places stringers of arsenopyrite traverse the formation in all directions. This mineral is very rich in gold, some of it running as high as 325 ounces of that metal to the ton. In a porphyry dike traversing the property is a small galena vein, from two inches to a foot in width, which has

been opened by surface trenching. This vein is rich in gold, samples assaying as high as 100 ounces to the ton, and it is probable that the Hanson galena-gold specimens, previously referred to, come from its continuation to the north of Poplar creek. No systematic development work has been done, such inconsiderable work as has been undertaken having been confined to surface trenching, the sinking of prospect pits and running a drift, apparently pocket hunting. From this property a mill-test of eight tons was made, yielding gross returns of $246.50.

Further south-easterly from Poplar creek considerable prospecting has been done and a number of locations made, on the majority of which veins have been found similar in character and mineral contents, but no development work of any importance, in spite of the fact that the showings are sufficiently good to warrant it.

On the writer's first visit to the Poplar creek district, as that portion of the mineral belt is called, lying between Rapid and Cascade creeks, he was favourably impressed by the number, and assay-value of the veins that had been opened up by prospecting, and the exceedingly rich samples of gold ore to be seen, but was at a loss to account for the fact that no real development work was being carried on and no effort made to turn the "prospects" into mines. On enquiry it was ascertained that immediately following the first strike of specimen ore in 1903, a rush took place into the district followed by a wild staking of claims in all directions, with the result that the same piece of ground was located several times over by different parties, and litigation was the natural consequence. In cases where there was no conflict in the matter of title, claim-owners asked exhorbitant prices and proposed absurb conditions to prospective purchasers, in spite of the fact that they themselves were not financially able to develop the properties. In one instance a cash offer of $25,000 for a single claim on which practically no work had been done was refused, and in another case the owners would not grant the privilege to anyone of even making a thorough examination of the property, with a view to acquiring a working-bond thereon, unless he first paid over several thousand dollars as earnest money. Naturally capitalists and engineers became disgusted and turned their attention to other mining districts, leaving Poplar to its own devices. This condition has now completely changed; litigation

has been settled and the present owners of the properties, with a few exceptions are only too ready and willing to listen to any business proposition having for its object the development and ultimate sale of their prospects. During the past two months three of the Poplar creek properties have been bonded and work will commence on them this spring. There are also several other "deals" pending, hence a revival of mining in that portion of the mineral belt may be expected this year.

LIME-DYKE MINERAL BELT.

This belt extends from Fish river on the north-west to beyond Lake creek on the south-east, its south-western boundary following the Lardeau-Duncan divide and its north-eastern boundary not yet determined. Topographically the country is similar to that along the Central Mineral belt, except that the mountain peaks are higher and more rugged, with frequently perpendicular cliffs a hundred or more feet high. The scenery is magnificent. The rocks of this belt consist of bands of limestone and slate cut and intruded by dykes of diabase and porphyry. The ore so far discovered lies chiefly in the lime and along its contact with other rocks. The strike of the formation is south-east, but the dip varies from north to south, on account of folding. Numerous claims have been staked and much prospecting done along this belt; but owing to the difficulties of transportation, the inaccessibility, and the greater facility with which the veins along the Central belt can be developed, properties here have lain dormant for some years. Among the more noted properties in the lime-dyke are: The Little Robert, situated on the divide, on the west side of the north fork of Lardo creek, near its source, at an elevation of 7,200 feet above sea level. The vein is quartz, from two to five feet wide, striking with the enclosing lime, but cutting it in dip toward the overlying slate. The ore consists of galena and gray copper, in bunches and scattered through the quartz. A small shipment of 200 lbs. yielded 110·8 ounces silver and 21·5% lead and another shipment of 5,000 lbs. yielded 114 ounces silver and 24% lead per ton. The development work consists of an open cut and shallow pit on the outcrop near the foot of a bluff at the head of a small glacier and a cross-cut driven through the hanging-wall slate to intersect the vein on the contact. The

cross-cut, however, has not been driven sufficiently far to accomplish this purpose.

At the head of Gainor creek, on the west side, is the Badshot group. The vein is several feet in width, strikes south-east and has a northerly dip through the lime toward the underlying slates, the ore, consisting of galena and gray copper, occurs in shoots. The development work consists of a cross-cut, an incline-shaft on the vein, and drifts both ways therefrom, making a total of three hundred feet. A shipment of 44,488 lbs. of ore yielded 157 ounces silver, 56% lead and 4·6% zinc, per ton. Selected samples of coarse-grain galena assay from 140 ounces silver and 80% lead to 144·2 ounces silver and 80% lead, samples of fine grain galena 345·1 ounces silver and 69% lead, and galena and gray copper 189·5 ounces silver to 226 ounces silver and 55% lead per ton.

At other points along the lime-dyke, at the head of McDonald creek, Porcupine creek, Cariboo creek, Haley creek, Lake creek, and Hall creek are similar ore occurrences. From some of the properties small shipments have been made all of which gave good returns, and on others are large bodies of low grade ore. There is no doubt that improved transportation facilities would result in the opening of a number of paying mines in this belt.

South-west Mineral Belt.

This belt has not been prospected to anything like the extent of the other two, for the reason that the rocks are more completely hidden by vegetation and soil, so that the only exposures are along the creek beds and in the bluffs, occasionally found along the mountain sides. The rocks composing this belt are schists, carbonaceous phyllites, bands of limestone and slates, bounded on the south-west by granite which, in places, sends out spurs into the adjacent rocks. Dykes of aplite and pegmatite are also present near the granite and are specially noticeable at the head of Canyon creek. The mass of the granite forms the backbone of the mountain range dividing the Trout lake and Lardeau river valley from that of the Upper Arrow lake, occupying their summits and coming well down on their north-eastern slopes. The other limits of this belt have not yet been determined. While a considerable number of locations have been made along the south-western mineral belt, few of them have been developed to any

extent except in the vicinity of the town of Trout lake and at the head of Canyon creek. This is attributable to the lack of proper trails from the main routes of transportation to the various prospects, and to the impossibility of taking pack animals anywhere through the country except along well built roads or trails. Aside from the two localities mentioned all supplies needed by the prospector for developing his claim have now to be carried in on men's backs, but the advent of capital and serious endeavours to develop the ore bodies would soon change this, as the government would build proper trails from the main routes of travel to the points of operation.

The Copper Chief group is situated on the south-west side of Trout creek, about five miles from the town of Trout lake, at an elevation of 5,000 feet above sea level. The veins occur in a steep hill-side, almost a bluff, conforming to the strike of the enclosing rocks but cutting them in dip. One vein is from eight to fourteen feet wide of massive pyrrhotite, carrying a little copper and silver, but so far not in commercial quantities. It is possible that further exploration may disclose ore shoots of value. The other two veins are of quartz, carrying galena, pyrite, zinc-blende, gray copper and chalcopyrite, in a belt of lime. One of these lies very flat, is from two to three feet wide and has been developed by two short drifts. The other is exposed in an open cut and is two and a half feet wide. A trial shipment of three tons of selected ore from these veins gave return of 225 ounces silver, 16% lead, 1·71% copper, and 17% zinc.

Adjoining the Copper Chief group on the north-east is the Horseshoe group at an elevation of 4,000 feet above sea level. On this property is a quartz vein, in lime, from a few inches to three feet wide, carrying seams and bunches of solid ore composed of galena, pyrite and gray copper, with a little zinc-blende. No assays of this ore are available. About three hundred feet of development work has been done on this vein, consisting of surface stripping, drifting and shaft sinking.

The Lucky Boy adjoins the Horseshoe on the south-east, at an elevation of 4,400 feet above sea level. This property is the most thoroughly developed of any in the south-west Mineral Belt, but is still merely a prospect. It is only three and a half miles

FIG. 5—Trout lake from the Ferguson wagon road.
A. Lucky Boy Mine. B. Francis Mine.

FIG. 6—Basin at the head of the North Fork of Canyon creek from the Linson View.
A. Pedro. B. Grand Solo.

from the town of Trout lake with which it is connected by an excellent raw-hide trail. The vein is of quartz, from a few inches to five feet wide, carrying galena, pyrite, zinc-blende, chalcopyrite, gray copper, and, near the surface, native silver. The ore occurs in bunches scattered through the vein and as a pay-streak of variable width. In dip, the vein cuts the formation to the south-west and in some places lies almost horizontal. It has been developed by several open cuts, cross-cuts, an incline shaft over two hundred feet deep, and six hundred feet of drifts from the several levels in the shaft, besides drifts from the cross-cuts. The pay-streak varies from four inches to three feet in width of solid ore. Four hundred tons of selected ore have been shipped yielding from 200 ounces silver and 20% lead to 300 ounces silver and 35% lead.

Near the head of Glacier creek, on its north-west side, but considerably above it at an elevation of 7,000 feet above sea level, and overlooking Trout lake, lies the Francis group. The vein is quartz in a belt of lime, of variable width, its mineral contents being galena, gray copper, zinc-blende, and pyrite which near surface weather to carbonates and oxides. Much of the ore runs high in silver with a little gold. A picked sample of the carbonate ore from near surface assayed, ·5 ounce gold, 1,110 ounces silver, 39·3% lead and 1% zinc. One lot of five tons shipped this winter averaged 307·1 ounces silver, 28·2% lead, 3·1% iron, 1·4% zinc, 54·4% silica, and 2·7% sulphur; another shipment of 1,150 lbs. yielded 560 ounces silver, 38·6% lead, 2·3% zinc, 37·6% silica and 3·1% sulphur and a third lot yielded 171 ounces silver, 17·6% lead, 2·7% iron, 1·9% zinc, 65% silica and 1·4% sulphur per ton. On the dump there is a considerable quantity of low grade silicious ore which will average 40 ounces silver, and 4% lead. The development work consists of drifts on the vein equivalent to about four hundred feet, some surface prospecting, and a cross-cut intended to cut the vein at a depth of five hundred feet, but which has not yet been driven far enough to accomplish this purpose. Sufficient development work has not yet been done to fully demonstrate the value of the property, but present results are encouraging.

In the basin at the head of Canyon creek the south-west mineral belt has been prospected to some extent and a number of claims located on the veins found there. The Linson View prop-

erty situated on the north-west side of the basin, at an elevation of 5,000 to 6,500 feet above sea level, has three known veins traversing it. No. 1 vein is in the granite, has a south-westerly course and north-westerly dip, and is of quartz from four to six feet wide, carrying galena, zinc-blend, pyrite and gray copper. It is developed by a cross-cut, and a shaft thirty-five feet deep, sunk at the intersection of the cross-cut with the vein. From the bottom of the shaft a level has been driven south-west for twenty feet. A shipment of 875 pounds of selected ore from this shaft and drift gave returns of 261·2 ounces silver and 12·3% lead per ton. This class of ore occurs in streaks and bunches in the vein, the balance of the vein being low grade. No. 2 vein lies between schist and lime, and is exposed in a slide close to the bed of a small creek where a cut has been made on it, at an elevation of 6,000 feet. It is from four to eight inches wide, of quartz carrying galena, pyrite and gray copper, weathering to carbonates, rich in silver. No. 3 vein, 50 feet higher up the mountain, is ten feet wide in a carbonaceous phyllite, and is composed of quartz with included fragments of phyllite and mineralized with galena, pyrite, and gray copper. The only development work done on this vein consists of open cuts, one of which is twenty feet long and shows the vein to be much broken and twisted at that point. Both Nos. 2 and 3 veins have a south-easterly strike and south-westerly dip.

At the head of the basin lies the Pedro group, at an elevation of 4,800 feet above sea level. Here there are two quartz veins which have been opened by a drift and open cuts. No. 1 vein is from two to three feet wide, carries galena, zinc-blende, pyrite and gray copper, with occasionally a little native silver. The No. 2 vein is one and a half feet wide of a banded structure, carrying galena, and gray copper. A test shipment of selected ore from the No. 1 vein gave returns of $96.50 per ton.

On the south-east side of the basin lie the Black Jack, Grand Solo and Ruby Silver groups at elevation of from 5,600 to 7,060 feet above sea level. On the Black Jack is a vein of blue mineralized quartz, eleven feet wide, in the centre of which is a band of white quartz, one and a half feet wide, carrying galena and gray copper. The blue quartz carries no gold and only 0·6 ounces silver per ton.

On the Grand Solo, is a quartz vein from two to four feet wide, which has been opened by two adits driven on its course, the lower one of which is at an elevation of 5,960 feet and the upper 5,960 feet above sea level. They are 110 and 60 feet long respectively. On the foot-wall side of this vein is a streak of galena and gray copper, from four to eighteen inches wide, selected samples from which assay 555 ounces silver and 17% lead to the ton. On the Ruby Silver property, the upper claim of which takes in a portion of the glacier, at the head of the north fork of Canyon creek at an elevation of 7,800 feet above sea level, is a vein of quartz, two to four feet wide, with a streak of galena and gray copper on the foot wall side, selected specimens of which assay 129 ounces silver, 30% lead and 4% copper. This vein has been developed by an adit driven on its course, a hundred feet long, and a number of open cuts. From the open cuts that have been made along the vein outcrop it has been proved that this vein is a continuation of the one on the Grand Solo.

In the foregoing only such ore occurrences have been mentioned as were personally visited by the writer or concerning which reliable information was available. There are others reported to be of some magnitude and importance. Sufficient however, has been said to show that the "Lardeau" is well endowed with mineral wealth and the day is not far distant when some of the prospects mentioned will become productive mines and the district will take its place among the important mining centres of the North American continent. After carefully investigating the veins in the several mineral belts, one is impressed by their number and the value of their mineral contents, and one wonders, why, with all this apparent mineral wealth, there are so few developed mines? The answer is that the first mining operations carried on in the Lardeau was by English capital, and unfortunately men were sent out to direct and manage the work, who knew little or nothing about practical mining, and who squandered money uselessly. One of the mines so mismanaged was the Silver Cup, which is to-day, under different management, one of the deepest mines in the district, and steadily productive. The district has also suffered from the operation of the unscrupulous promoter, who as usual mined the public instead of the ground. These two facts,

coupled with the absurd prices or terms imposed by prospectors for their properties, have resulted in giving the district a "black-eye." But conditions are now changing. Prospectors have realized their mistake and are prepared to entertain any reasonable business offer, and the record now being made by the few operating mines is stimulating outside interest. With the provision of adequate capital and proper technical and business management, there are many prospects in the Lardeau which are capable of becoming productive mines, and will one day justify in the fullest manner possible the faith in the district's possibilities held by those who have investigated its mineral resources.

MINING IN ATLIN, BRITISH COLUMBIA, 1898–1908.

By Rosalind Watson Young, Victoria, B.C.

An attempt will be made in the following pages to give the history of mining in Atlin, British Columbia, for the past ten years.

During that period, from streams draining an area of less than fifteen square miles, about six millions of dollars have been obtained. It must be remembered that an exact estimate of the gold extracted can only be approximated. The Provincial Government levies a two per cent. mineral tax upon all output exceeding two thousand dollars; and the annual output is computed largely, though not solely, on the amount for which royalty has been paid. As may be supposed, each year a great deal of gold passed out of Atlin without being declared for royalty, hence without being in any way recorded.

The following figures are obtained from the reports of the Minister of Mines.

Output Atlin Mining Division for years 1898–1908:—

1898	$ 75,000
1899	800,000
1900	450,000
1901	300,000
1902	400,000
1903	440,000
1904	530,000
1905	475,000
1906	455,000
1907	408,000
1908	200,000
Total	$4,533,000

PER CAPITA YIELD OF GOLD.

This total furnished by the Government is a conservative one and personally the writer does not hesitate to place the total output at six millions. As the average number of men actually engaged in mining has each year been about six hundred, the per capita yield of gold has been one thousand dollars.

Attention is directed to the small returns for 1908, which are accounted for by the fact that, of the three largest companies, one did not operate, and the remaining two operated to a limited extent being engaged in improving their water systems.

DISCOVERY OF GOLD.

Prior to 1898, nothing was known of Atlin beyond its being a country of lakes and mountains in far Cassiar. The manuscript map of George Davidson explaining the "Map and Trails of the Chilkaht Chief, Koh-klux, 1852" shows a lake called "Ahtleen"—the original form, evidently, of the word Atlin.

In the spring of 1898, Fritz Miller, a German, and Kenneth MacLaren, a Canadian, left the Klondyke trail at Bennett and crossing the ice of Taku Arm and Lake Atlin found themselves on Pine Creek. Six miles from the mouth of the creek they staked Discovery claim. Development has proved this the most enriched area so far uncovered, the southern bench showing no sign of exhaustion.

To secure supplies the two prospectors made their way to Juneau, Alaska. On their return they were followed, and by August Thirteenth news of the "Gold Strike" reached the Government at Victoria. Before the Autumn of that year, three thousand people, it is estimated, had rushed to the camp and all available ground was staked. It is noteworthy that all the creeks that have been gold producers were staked that first summer. Some have been abandoned several times and restaked but have not yet reached the productive stage, though viewed as good prospects. The results of that first season's work could not be ascertained but have been estimated officially at seventy-five thousand dollars ($75,000).

Only four hundred people wintered in Atlin, but in the following spring there were thousands of new arrivals.

Claim-Jumping.

The first locators were uncertain whether Atlin was in British Columbia or the Northwest Territories, and the Mounted Police claimed it for the Territories. Now a placer claim in the latter was 250 feet, and in British Columbia 100 feet. When, therefore, it was established that Atlin was in British Columbia, the 250-foot claims were "jumped" and abundant material was prepared for years of litigation.

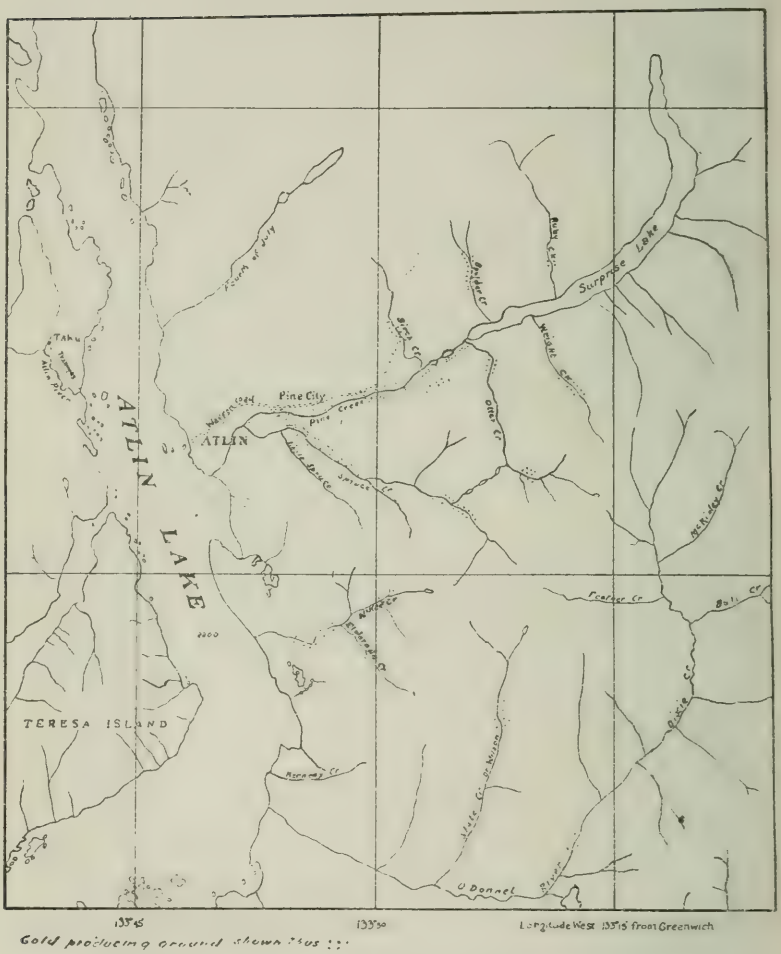
Alien Bill.

Another trouble befell the new camp when in 1899 the British Columbia Government passed an amendment to the Placer Act, excluding all who were not British subjects from holding claims. This "Alien Bill," as it was called, was disallowed within a year, but already harm had been done. Soured with the place, hundreds of aliens had left. The absence of experienced miners became marked. Capital was withdrawn and has ever since been shy.

At first all matters of dispute had to be referred to the Government at Victoria. In 1899, a Special Commissioner was sent by the Government to Atlin to settle disputes. Subsequently a Supreme Court judge visited Atlin each summer. In 1904, Atlin was made a county for judicial purposes. Since the appointment of a County Court judge, it has become unnecessary for a Supreme Court judge to visit the camp. After the first few years the powers of the Gold Commissioner were enlarged, so that he could adjudicate upon many mining matters.

Gold-Bearing Creeks.

With the exception of what has come from McKee Creek, practically all the placer gold of Atlin has been derived from the Pine creek valley, which is a wide valley extending some twenty-five miles eastward of Atlin Lake, and flanked to north and south by low ranges. The valley is drained by Surprise lake and Pine creek with their tributaries,—Ruby, Boulder and Birch on the north; Wright, Otter, Gold Run, and Spruce on the south.



Sketch Map showing Gold-Bearing Creeks, Atlin, B.C.

Geological Formation.

In 1899, the Geological Survey was represented by J. C. Gwillim, B.Sc., who made a log and compass traverse of the lakes, and a paced survey of the country travelled by land. In his excellent report he shows that the "Gold Series" consists of magnesite, serpentine, peridotite, and actinolite slate. Intrusions of granite cut this series off on the north; to the south are quartzites, slates and limestone. Most of the gold has been found in the Gold Series, a little in the slates, and almost none in the granite.

Study of Gravels Desirable.

Practically no work has been done in the District by the Survey since 1899. The field is a most interesting one for the study of gravels, and great assistance would be rendered the miners by having skilled geologists investigate the old water courses.

There have been several runs of gold but the richest and most wide-spread occurs in the "old yellow deposit" of pre-glacial origin. At first, both on Pine and Spruce creeks blue gravel was found overlying the yellow, but as work advanced on the benches the blue gravel disappeared leaving only the yellow.

The average value of the gold is twenty dollars an ounce.

Relative Value of Creeks.

The leading creeks, in order of production, have been Pine, Spruce, and Boulder. The following table, compiled from Government Reports, shows the amounts upon which royalty was paid in the various years from 1899 to 1908:—

AMOUNTS UPON WHICH ROYALTY WAS PAID ACCORDING TO CREEKS

CREEK.	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	TOTALS.
Pine	$276,564	$98,360	$44,840	$62,246	$107,655	$107,318	$91,925	$105,497	$152,982	$46,719	$1,094,106
Spruce	45,405	33,980	46,642	67,029	99,695	101,557	99,048	86,020	81,080	41,235	701,691
Boulder	48,800	38,320	42,507	93,444	85,916	107,906	132,915	49,474	54,993	15,200	669,475
McKee	54,580	34,660	11,172	29,814	10,756	57,191	27,575	33,550	23,329	27,900	310,527
Wright	74,980	21,360	4,750	6,002	1,550	3,365	3,872	5,873	8,509	2,115	132,376
Willow	20,047	.....	42,891	.....	.....	.....	.....	.....	.....	.....	62,938
Birch	2,875	300	4,300	.....	6,635	16,100	3,144	5,000	5,670	15,047	59,071
Otter	5,490	2,440	2,220	2,635	437	.....	.....	3,952	5,347	4,160	26,681
Various others	2,850	380	3,387	642	.....	.....	.....	2,887	8,078	5,782	24,006

Pine and Spruce, the largest producers, differ in this respect, that while the bulk of the gold from the former has been won by companies, from the latter it has been secured by individuals and partnerships.

For the first three years 1898, 1899, 1900, ordinary placer methods were employed. Especially for two and a half miles on Spruce creek, Chinese pumps, waterwheels, drains, ditches, sluice boxes and wingdams crowded each other. Pick and shovel work produced good results.

Size of Placer Creek Claim.

It did not take long to find out that 100-foot claims were too small to mine, and stack tailings upon. So in 1901, the size of the placer claim was increased to 250 feet square. Time proved that even this was inadequate. In many cases, it was only by consolidation of claims that work could proceed smoothly. When owners of adjoining properties disregarded the "give and take" principle, mining was impossible. Bench owners had to wait till creek claims had been worked out before they could get their share either of water or dump.

In 1906, the Placer Act was amended to make the width of the claim from base to base of the hill and 250 feet in the direction of the stream.

1000 ft. x 250 ft.

Difficulty in determining what was the base of the hill when slide-material was present, led to an amendment in 1908, making the placer claim 1000 ft. wide and 250 feet in the direction of the stream. This change appears to have given satisfaction.

Hydraulic Leases held for Speculative Purposes.

The shallow ground was soon worked out and it became necessary to instal hydraulic plants. Already there had been much staking of hydraulic leases. Such leases are not supposed to be granted for ground that can be worked by simpler placer methods. Through fault of the Gold Commissioner, some such leases were granted and tedious law suits resulted. In many cases leases were held purely for speculative purposes. In the

years 1899, 1900, 1901, two hundred and fifty-eight hydraulic leases were issued. During the last five years the government has rigidly enforced the cancellation of all leases which did not comply with statutory conditions. In all, two hundred and fifty-three leases have been cancelled, whereby much ground has been thrown open for restaking.

HYDRAULICKING.

Hydraulic methods were inaugurated in 1900. Although other phases of mining have since been tried, none have been more successful than hydraulicking. Three companies that have operated on a large scale are: North Columbia Gold Mining Co., Pine Creek; Amalgamated McKee Creek Mining Co., McKee Creek; Société Minière de la Colombie Britannique, Boulder Creek.

NORTH COLUMBIA GOLD MINING CO.

The most extensive hydraulic operations are conducted on the south bench of Pine Creek, opposite the town of Discovery, by the North Columbia Gold Mining Company. This company was formed in 1904 and has secured the controlling interest of the Pine Creek Power Company, which was originally the Sunrise Hydraulic Partnership. Rich ground was purchased adjoining the upper leases of the Pine Creek Power Company.

DRIVING-GRAVEL.

Ordinarily three pits are worked and four giants with seven-inch nozzles are used in each pit, three to drive the gravel into the sluice, and one to trim the dump. It has been found that the water is much more effective when it drives the gravel than when streams play upon the face and the back wash carries the gravel to the sluice. The pits are double-compartment with two lines of sluice, so that when one sluice is being cleaned, piping goes on in the other compartment. Thus time is saved, which is a secret of success. In a country where the season is short it is imperative that the water should be fully utilized if work is to be profitable. The North Columbia company each year extends its working season hopeful that it may yet secure seven to eight months work, i.e., April to November.

A Pit on Spruce Creek, Atlin, B.C.

A View of Pine Creek, Atlin, B.C.

The depth of gravel is about 45 feet, consisting of 5 to 6 feet of top soil and loose gravel, 15 feet blue glacial clay, 14 to 26 feet yellow gravel. Bedrock is magnesian and so soft that it can be cut down about four feet. It is thirty feet above the level of the creek. The gold values are in the yellow gravel, especially the five feet nearest bedrock. The whole deposit, barren clay inclusive, runs about 40 cents per cubic yard.

Blasting.

Owing to the compact character of the gravel, and the low pressure of water hitherto available, blasting on a large scale has been necessary. In a single blast 2,000 to 3,000 pounds of seventy-five per cent. powder were used, the method being to run drifts and T's, so that charges of powder could be placed every twenty-five feet over the whole area of ground to be blasted. The biggest charges, about two hundred pounds each, were placed at the back of the drifts. Time and labour were saved and the eificiency of the blast increased by using water for tamping. To outward appearance the blast was a failure, but when piping began the good effect was apparent. The gravel was found to be perfectly shattered and the washing of it as easy as surface stripping.

Though efficient, such blasting was costly. In future, it will be unnecessary, it is hoped, because the volume and pressure of the water have been increased. In 1906 a crib dam was constructed across the lower end of Surprise Lake, which is a natural reservoir, fifteen and a half miles long by three miles wide.

Ditch of 15,000 inch Capacity.

In 1907 and 1908 a ditch five miles long, 26 feet wide at a minimum depth of 6 feet, and capacity of carrying 15,000 miner's inches of water, was excavated by means of a one-yard dipper shovel. Hence this company is now in a very enviable position having abundance of water, with the "old yellow deposit" extending to unknown distances.

McKee creek is in possession of two companies, the Amalgamated McKee Creek Company, and the McKee Consolidated Hydraulic Company, under one management. The "Amalgam-

ated" bought out the Atlin Mining Company or Nimrod Syndicate. The output from this property is reported to have been $232,000.

1902	$24,000
1903	48,000
1904	52,000
1905	22,000
1906	32,000
1907	24,000
1908	30,000
Total	$232,000

In 1908, the water supply was increased. A steam shovel, an electric haulage system, and a washing plant near the lake, are now contemplated.

La Société Minière de la Colombie Britannique installed its plant on Boulder creek in 1901. Its success has been varied as may be gleaned from the following amounts upon which royalty was paid:—

1902	$ 24,000	
1903	19,000	
1904	60,000	All taken out by "lay-men."
1905	103,000	Nearly all taken out by "lay-men."
1906	23,500	
1907	40,000	
1908	13,000	
Total	$282,500	

For some time, there was bad feeling between this company and the "individual miners" of the creek, on account of tailings. In the end the company secured a perpetual injunction restraining certain miners from ground sluicing. If expenses were kept as low as possible, this company should prosper.

On Birch creek the output is limited by the water supply. In 1908, the hydraulic company had water enough for only two hours' piping in every twenty-four; nevertheless they uncovered over 4,000 square yards of bedrock and obtained $10,000. What is required is capital to improve the water system.

Pine Creek Power Co., Atlin, B.C.

DREDGING.

The success in placer-dredging met with in Oroville, California, was so conspicuous that hopes ran high that a dredge was the proper device for handling the Atlin gravels. The trial was made by two companies—the British America Dredging Company and the British Columbia Dredging Company.

The British America Company installed its dredge on Gold Run in 1903 and operated it in 1904 and 1905. The British Columbia Company completed its dredge in 1905, operating it 58 hours in that year, and one month in 1906.

Both dredges were built by Bucyrus Company, of Milwaukee, at an approximate cost of $100,000 each, and were electrically equipped, of endless chain type, with theoretical capacity of 3,000 yards a day. The British America dredge was originally intended for leases at the mouth of Pine creek, but as miners drifting on Gold Run had done exceptionally well, it was decided to purchase ground there, that there might be every opportunity of success. Digging began in 1904. The ground proved to be 32 feet in depth, consisting of 8 feet surface dirt, 3-8 feet yellow gumbo, boulders and cemented gravel to bedrock, and bedrock hard. By the close of the season little gold had been recovered, and the buckets were in a battered condition, all requiring new lips.

In 1905, the dredge was taken from winter quarters and placed in repair. A Keystone drill, meanwhile, made holes for blasts. The holes were about 40 feet apart and 25 pounds of 75 per cent. powder were used for each blast. As a result the digging capacity of the dredge was at least double of the previous year; but even so, it dug only one-tenth of its theoretical capacity. The gross yardage was about 30,000 yards. The working season was cut short by the breaking of the main driving shaft and of the grizzly shaft. Though the shafts were repaired, it was deemed advisable after finishing the cut then engaged upon, to dig a hole for beaching the boat. The actual run was about 88 days. Operating expenses amounted to $18,000. What gold was recovered was not announced but was known to be inconsiderable.

The British Columbia dredge on Spruce creek was in every way—save results! superior to that on Gold Run. It was of open-connected type, with 32 buckets on the chain, each bucket having a capacity of 7½ cubic feet.

In its proportions it was similar to the Gold Run dredge, being 90 feet long and 45 feet wide. Its superiority lay in the size and open-connected type of the buckets, in having a main driving belt instead of a sprocket chain, in the strength of its machinery, in the gold saving appliances, and in the disposal of the tailings—the Gold Run dredge had no stacker.

The boat was built in 1905, a fine piece of workmanship, and made a test run of 58 hours, the gross yardage being 10,000 yards. The gravel was 14 feet deep containing immense boulders. Beneath this was a false bedrock of clay, underlain by a glacial deposit of undetermined depth.

At the conclusion of one month's work in the following season, dredging operations were discontinued. The boulders were too numerous and the gold was not being saved. In the end the boat was dismantled, the machinery shipped to Dawson, and the hull left to show how the money of investors had been ruthlessly squandered. Had the first dredge been placed on the modern gravels at the mouth of Pine creek, as was originally intended, there would most surely have been a happier story to tell. Where dredging has been most successful, the gravel is loose and free from large boulders, bedrock soft, and the gold fine and uniformly distributed. Neither at Gold Run nor at Blue Canyon, Spruce creek, did the ground conform to these conditions.

The only valuable asset left to the B. A. D. Company, is the power-house that was built on Pine creek below the Falls.

Steam Shovel.

The steam shovel was the next experiment, and a more successful one. In 1905 The Northern Mines Limited purchased three-quarters of a mile of the richest part of Spruce Creek, which prospected two to four dollars per cubic yard, and thereon installed a 26-ton traction wheel shovel manufactured by the Vulcan Iron Works of Toledo, Ohio. Though the capacity of the shovel was theoretically a thousand cubic yards a day, in actual practice it was three hundred to four hundred yards, the gravel being sixteen to thirty feet deep. The first season promised success, but owing to limited capital, the company economized by purchasing a second-hand boiler and hoisting plant, with the

result that only one skip could be operated, thus causing shameful waste of time. In the second season there was friction in the local management. An unskilled crew was "hard" on the shovel. Breaks occurred: and shutting down for repairs with twenty men on the pay-roll at five dollars a day, was expensive work. The season closed with the company in arrears for wages and supplies. But the failure was *not* due to the shovel, which had satisfactorily handled the gravel.

Guggenheim Shovel.

Meanwhile a more powerful shovel had been installed by the Atlin Consolidated Mining Company (Guggenheim capital) on Tar Flats, situated on the north bench of Pine Creek, about a mile above Discovery. The shovel was a 70-ton Bucyrus; $1\frac{3}{4}$ yard dipper. For the digging engine, one hundred horsepower was required; for the swinging and dipper engines thirty horsepower each. The fuel used was wood, of which five to six cords was the daily consumption. There were four dipper teeth, sixteen inches long when new, but constant friction soon wore them down. The boom was long enough for a cut forty feet wide.

Digging began August 15th, 1906, and continued until September 18th, during which time 12,100 car loads of dirt were discharged into the sluice, making a rate of 1,500 cubic yards per day; for in the given period the shovel was shut down on one occasion for four days and on another for five days. The record run was 468 cars or 1404 cubic yards in nine hours.

The height of the working face was 18 feet. The gravel was yellow, compact, uniform, with few boulders too large for the dipper. Bedrock was serpentine mixed with soapstone, soft enough for the shovel to dig into two to three feet. No blasting was necessary the first year, but was found advisable the second season. Cuts were made 900 feet long and 40 feet wide. The rails on which the shovel ran were in six-foot sections and held by bridles to render spiking unnecessary. The shovel advanced six feet at a time and, ordinarily, two or three times each shift.

Haulage System.

Eighteen cars, divided into three trains of six cars, each drawn by a locomotive, were employed. These trains were

so disposed that while one was being filled, another was discharging into the sluice and the third, empty, was waiting on the siding ready for its turn at the shovel. The cars were side-tripping, of 3 yard capacity and run on three-foot gauge track with thirty pound rails. A train went by electricity to the foot of the incline, where a switchman hooked the cars, three at a time, to a $1\frac{1}{8}$-inch cable connected with a 75 horsepower hoist.

INCLINE.

The incline was constructed about five hundred feet from the lower end of the company's ground. It had an angle of 30 degrees, and was double-tracked, its platform 45 feet above the pit floor. Two men were stationed on the platform to trip the cars, keep tally of the number received, and start the empties, which then ran down by their own weight.

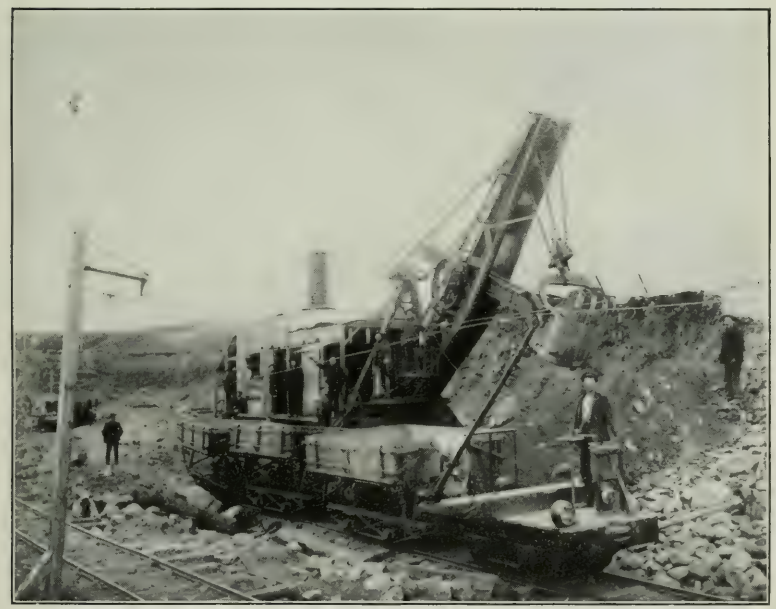
GOLD-SAVING APPARATUS.

In the platform were four bins, into which the cars emptied. The auriferous material fell on a grizzly, of which the steel bars were set at an angle of thirty degrees and eighteen inches apart. The "oversize" fell on the dump, while the "undersize" dropped into the 4 x 4-foot sluice. The sluice was 200 feet long with two Y's to better distribute the tailings. The grade was 8 inches to 12 feet, with the exception of the first twelve boxes, where the grade was one inch to the foot. The first three boxes were paved with 45-pound steel rails, the remainder, except the extreme ends, where blocks were used, with steel angle iron 3 in. x 3 in. x $\frac{1}{2}$ in. An undercurrent was used only when cleaning up, as without it the water did better service on the tailings pile. Ten to twelve pounds of mercury were thrown into the sluice every other day. One thousand inches of water was conveyed from the "Miners' Ditch", by 800 feet of 26 to 28 inch steel pipe to the head of the sluice-box.

NUMBER OF MEN EMPLOYED.

For operating the plant, thirty men were employed in two ten hour shifts. Seventeen on the day shift were disposed as

The Guggenheim's Syndicate 70-ton Bucyrus Steam Shovel on Pine Creek, Atlin, B.C.



Steam Shovel on Pine Creek, Atlin, B.C.

follows:—Engineer, craneman and fireman for the shovel, 3 motormen, 1 switchman, 1 man for hoist, 2 men for tripping cars, 4 pit men for cleaning bedrock, laying track, etc.; 1 blacksmith, 1 blacksmith's helper, 1 carpenter.

From the British America Dredging Company's power house an alternating current of 22,000 volts was obtained. In the transformer house a step-down was made to 460 volts to operate the hoist and lower for lighting purposes. For the locomotives direct current was generated from the alternating current.

Values Saved

The gravel was worth about fifty cents per cubic yard. Working expenses were about $250 per day. The original cost of ground and plant amounted probably to not more than $150,000. In the two seasons' operations royalty was paid on $100,000, which was a very creditable showing.

In 1908, a new superintendent was placed in charge, who decided that the plant needed a complete overhauling. He also concluded not to operate that season, but to await the results of experiments being made elsewhere with an improved type of machinery.

Of modern methods, the steam shovel is the most practicable yet discovered for handling Atlin gravels.

New Fields for Activity.

In several new directions the outlook is bright for coming years and especially at Ruby Creek and O'Donnell River. Ruby creek, which empties into Surprise Lake, has for years been regarded as an ideal hydraulic field. Complete control could be obtained of the creek; water and dump were excellent; and prospecting had revealed a pay-streak at least 170 feet wide. The depth to bedrock was 47 feet with 25 to 30 feet in pay. Experts looked at it. Some took options, but went no farther. In 1908, however, the property was bonded, prospected, and the bond taken up. An hydraulic plant will be installed forthwith.

Another promising section is the O'Donnel River, the largest river flowing into Atlin Lake. It is thirty miles long with numerous tributaries. Here, Robert McKee, who was the discoverer

of gold in Spruce and McKee creeks, with pick and shovel has made $10 to $20 per day. Last winter, 1908, he organized a company intending to thoroughly prove his ground. Should his expectations be fulfilled a very large area of new territory will be opened up.

MAGNESITE DEPOSIT.

In the rear of the town of Atlin is a unique deposit of hydro-magnesite. Its white surface extends over two to three hundred acres; its depth is undetermined. Its origin is believed to be due to the action of mineral springs in the magnesian rock. A trial shipment of 200 tons was made to San Francisco in 1904. Owing to excessive moisture it netted only one dollar a ton.

The magnesite is of pure quality as shown by the following analysis made in the Government Laboratory:—

Alumina	trace
Iron	trace
Sulphates	none.
Chloride	"
Silica	1.12%
Carbonate of Magnesia ($MgCo_3$)	88.62%
Oxide " (MgO)	9.44%
Moisture	0.80%

It is used in the manufacture of fire brick, Portland cement, wood-pulp, etc.

Recently British capitalists have made a first payment on the property. It is likely that the material will be dried and shipped crude. One strange feature about the deposit is that it seems to increase in bulk, due, it is believed, to the chemical change from oxide of magnesia to carbonate of magnesia. The hole out of which the two hundred tons were taken very soon disappeared.

BEAVIS MINE.

When the Conrad mines were opened up at Windy Arm, Yukon, in 1905, an impetus was given to prospecting for minerals. Development at Windy Arm has been slow. Undoubtedly there are good mines there, but for reasons best known to the owners, work has been held back. The Atlin prospects including free milling quartz, copper, and lead have in most cases not been devel-

oped any more than is required for assessment work. At the Beavis mine, within a mile of Atlin, a shaft has been sunk 175 feet and 425 feet of drifting done, with results said to be satisfactory.

Engineer Group.

On Taku Arm, south of Golden Gate, the Engineer Group of claims has been staked for many years. The ore is free-milling quartz and very rich stringers occur, containing tellurides of gold.

A shipment made in 1908 is reported to have given values of $65.00 to the ton.

Coal.

In the fall of 1908, coal was discovered at the south end of Atlin lake. The quality appeared good and suitable for coking, but it was too late in the season for any extensive examination to be made as to quantity.

Coal was also discovered in Rainy Hollow, which is in the extreme north-west of the Atlin Division, and approached from Haines Mission by way of Porcupine district, Alaska. Though Rainy Hollow was located in 1898, it has witnessed little actual development. It contains copper and iron deposits and, if the coal discovered is of sufficient quantity, the success of mining in that quarter is assured.

Conclusion.

The writer has imperfectly traced the ups and downs of mining in the Atlin Division during the first decade. It must be admitted that the pioneers met with many disappointments and had much to learn from hard experience. As in all mining communities the population has been transitory. Comparatively few "old-timers" will make the history of the second decade.

The camp is *not* worked out. There is good ground in abundance but capital is required to win from it the gold. Spruce creek, for example, has produced about a million of dollars. In places the paystreak has been traced for a width of a thousand feet and the end not reached. Tailings washed a second and third time have yielded more gold than at the first washing.

A company in control of this creek, with plenty of water and a bed-rock flume, would have a paying investment for more than a lifetime; in British Columbia, the opportunities for profitable investment at the present time are so numerous, that it is hard to coax capital to out-of-the-way places.

GOLD DREDGING IN BRITISH COLUMBIA.

By Arthur E. Hepburn, Vancouver, B.C.

In presenting a paper dealing with the subject of gold-dredging in British Columbia, the writer hopes, by comparing conditions in this Province with those existing in other countries, to indicate the causes for the non-success heretofore of an industry, which elsewhere, and under less favourable natural conditions, has succeeded so well. At the present time, it may be observed, dredging areas are being acquired and large sums spent in dredging enterprises in the far north, on the verge of the Arctic Circle, where the working season is limited to a few months in the year, and where the ground is solidly frozen to bed-rock; and despite these drawbacks large fortunes are being won. But here at our very doors are richer and better fields for dredging enterprises; while, too, the facilities for working are eminently more favourable. If then the cause of past failure can be ascertained, it may be expected that attention will again be directed to this important and remunerative branch of industry in the Province.

The mining districts of British Columbia number in all about twenty, but in four only has dredging been carried on to any considerable extent, namely: Cassiar district, Cariboo district, Lillooet district and Yale district. A review of operations in these districts is annually published in the "Report of the Minister of Mines," and may be consulted by those desiring the information. The record, however, is one of almost unvaried mishaps or failure.

In the United States, where this branch of mining has been reduced to a science, dredging is carried on in numerous instances at a considerable profit. In order to investigate the conditions contributory to success in this direction, the writer recently visited the Sacramento Valley in California. The deposits on the eastern side of this valley lie at the base of the western slopes

of the Sierra Nevada, and gold is found in the several streams debouching from the canyons. The deposits are all gravel, clay and silt. At the time these deposits were formed, the valley was a fresh water lake, which gradually filled up with detritus from the Sierra Nevada mountains. The gold bearing gravels of this deposit are of hard siliceous rock, well worn and rounded, and the gold found is fine flour gold, derived from ancient quartz reefs.

Operators in this district have displayed much common sense in the selection of ground, often rejecting otherwise rich areas, if the conditions were not suitable for dredging. Plant, moreover, has been specially designed to meet local requirements; while careful consideration has been given to every detail of working. The result is that these undertakings are invariably profitably conducted. In California, experience has taught that to carry on dredging successfully, the following conditions must obtain:—

(1) The auriferous area must be sufficiently extensive to warrant capital outlay.
(2) The material should be uniform in character. Otherwise it is not possible to design a plant to work economically and satisfactorily.
(3) The depth of bed-rock should not be below the reach of the dredge.
(4) Bed-rock should be soft enough to enable the lip of the dredger to cut its surface; otherwise the gold, lying on the bed-rock and in its crevices, frequently constituting the principal source of wealth of the property, will not be recovered.
(5) The supply of water available must be sufficient both for floating the dredger and for washing the dirt.
(6) The physical obstacles, such as excessive overburden, frozen gravel, etc., must not be so great that, to overcome them, cost would be excessive.

If these conditions are satisfactory, it is always possible to design a plant that will afford successful results; but on the other hand, if any of the above conditions are unfavourable, failure may be usually expected to follow. The Californian

TYPE OF DREDGE IN USE IN CALIFORNIA.

Manufactured by the Link Belt Co. of Chicago. The illustration shows the sand pump at work.

experience is that large and powerful plants are alone of service. The first cost of these is necessarily higher than that of lighter and weaker plants; but the former is effective, while the latter is not. Again, the force of men required to work a heavy plant is the same as would be employed on a lighter dredger; and while a consumption of fuel, on account of the increased horse-power is, of course, greater in the former case, this is offset by the increased and lessened cost of the daily output, the fewer stoppages for repairs and the fact that the larger plant is capable of working in ground which is beyond the capabilities of the light dredger to handle. The Californian dredger is designed to reach at least sixty feet below water surface level, and the gold-saving appliances are expected to save the fine flour gold. The cost of renewals are estimated at 36% at least of the original cost of the plant; in a weak machine this percentage would be very much higher.

It may be noted here in passing that when gravel is cemented, necessitating the use of dynamite to break it, the value of the ground per cubic yard should be higher than that of the loose gravel worked, as not only will the expense be greater for drilling and blasting, but usually it is necessary to work the ground over a second time, since the cementic fragments passing through the screens of the dredger, break with difficulty and carry much gold away with them.

With the knowledge gained in California, the writer visited the gold dredging areas of Canada, and in most instances found conditions here to be very similar to those obtaining in the South, with the exception, of course, that in our more northern latitudes the working season is shorter.

The first excursion was up the Fraser River, which, for a considerable stretch from the mouth, contains silt-covered flats with gravel below at great depth, and if gold exists, it could only be in very minute quantities carried down by the current from the natural riffles of the bars higher upstream. Above Agassiz, however, Chinamen were observed washing and saving the fine gold that the current had brought down through the Fraser Canyon. The bars between Agassiz and the canyon contained much fine gold, and here apparently is ideal dredging ground, although, of course, no definite opinion can be expressed until the area has been properly prospected by drilling. It is believed that this river

stretch is now held by a number of companies, having leasehold rights thereof. After passing through the canyon of the Fraser River a broad valley opens up, just beyond which is situated the little town of Lytton, where, near the mouth of the Thompson River which enters the Fraser at this point, dredging has been undertaken, using, it is understood, a dredge of the New Zealand type. The current of the Fraser here is apparently very swift and hence would make dredging a somewhat risky undertaking. Leaving the Fraser at Lytton, the writer proceeded up the Thompson River to Kamloops, visiting Ashcroft en route. Between Ashcroft and Kamloops Lake the possibilities for dredging enterprises appear to be most promising, and several groups of Chinamen were observed sluicing on the bars and were said to be doing well. The banks on either side of this stream are terrace benches. Near Ashcroft the Bonapart Creek flows into the Thompson River. In the early days of mining in the Province much gold was recovered from this creek, and it is not unlikely that values are still contained in the deeper gravels. Another stream that formerly yielded good returns is Dead Man's River, a short distance east of Penney's.

The Basin of Kamloops Lake collects such gold as may come down stream from the upper reaches of the Thompson. About a mile from its head and some nine miles distant from the Kamloops, is Tranquille Creek, which, at one time, yielded a considerable amount of gold. It still contains gold at depth, while values may also be found nearer its source where the stream flows through the mountains. The bed of the river between Kamloops Lake and Kamloops consists chiefly of silt; bed-rock has, it is understood, never been reached and the gravel lies at a great depth. Approaching Kamloops the valley very appreciably widens out and, at the town, the North Thompson River joins the Thompson. East of Kamloops, the Thompson River is a mere sluggish stream and its bed contains no values. Up the North Thompson River the country changes very slightly for the first few miles, but gradually the valley converges and at a distance of about twelve or fourteen miles a series of riffles, bars and benches are encountered all more or less auriferous; while a number of small creeks, whose gravels carry values to a considerable extent, flow into the main stream. The river continues thus for seventy-

TYPE OF DREDGE IN USE IN CALIFORNIA.
Manufactured by the Marion Steam Shovel Co.

three miles to its junction with the Clearwater, which latter stream is so named on account of the clearness of its water, while that of the Thompson River is silty. The Clearwater is said to be auriferous.

On the Thompson River, between Jamison Creek and the first riffle, dredging operations have been carried on for some time past, the ground having been superficially operated, yielding at or near the surface about 6½c. to the cubic yard. This return proving disappointing, work here was suspended and the dredger moved to Tranquille Creek, where operations were again carried on for a time. This dredger was of the New Zealand type. Much of the fine gold was lost at first on the tables, but subsequently this defect was remedied and practically all the gold was saved. The machinery apparently, however, was not sufficiently strong for the work, as there were constant breakdowns and much time was lost in undertaking repairs. In dredging on the Thompson River a layer of clay was encountered at some depth below the bed. From this clay a few nuggets of small value were obtained; but had the clay been penetrated and the gravel below tested, there is reason to believe that better values would have been secured; for the gravel above the clay was evidently of recent deposition, and the gold therein was derived from the disintegration of the benches. The writer is of the opinion that systematic testing of the North Thompson and of the numerous creeks flowing into it above the first riffle, by drilling, would prove that these streams could be profitably worked by dredges.

The next point visited was Quesnel in the Cariboo district, which is reached from Ashcroft by the government road. The Fraser River gold is very fine and is chiefly found in the bed of the river and the terraces forming its banks. Very little gold is found in the Tertiary beds, but erosion thereof has resulted in the concentration of the gold in the lower terraces and in the river; and in places this concentration is sufficient to admit of profitable working. At the junction of the Fraser and Quesnel Rivers, sixty miles above Soda Creek, dredging was attempted with a machine of the dipper type, but proved unsuccessful; notwithstanding that, in the writer's opinion, conditions here are in every respect as favourable to dredging as in California.

Barkerville, situated some eighty miles distant from Quesnel, was reached on horseback. The intervening country is mainly a

Quarternary drift. The Quesnel River, the course of which the road at first follows, has very little fall, and its bed is chiefly composed of fluviatile and glacial deposits; while, like the Fraser, its banks are terraced. The tributary streams for some distance from the Quesnel likewise have very little fall, but nearer their source they rise very rapidly. In the Barkerville district the greater part of the gold recovered is found in the upper reaches of the tributary streams and within a radius of about twelve miles of Barkerville. According to the Geological Survey of Canada, the auriferous deposits of Barkerville are due to the tertiary rivers. The majority of the present streams flow along the lines of the ancient rivers, but between is a heavy layer of modern detritus. On Williams Creek the workings, at the time of the writer's visit, had been carried down to a depth of 90 feet and on Lightning Creek to 110 feet. Most of the gold found in the Cariboo district occurs at depths below forty feet. The ground has been chiefly worked by shafts. From an open pit 90 feet deep, the first 15 feet proved to be old tailings and gave values as high as 15c. to the cubic yard; this was followed by 15 to 16 feet of gravel containing no value; next in order was a thin layer of clay succeeded by gravel, the pebbles increased in size towards the bottom, although no large boulders were present. In the lowest 6 feet of this gravel values were found up to $6.00 per cubic yard. In the case of another property a boring was made to a depth of 287 feet showing the following section: For the first 100 feet alternating gravel and clay containing no gold values; next, 150 feet of blue clay succeeded by 30 feet of gravel and clay to bed-rock; the gravel for a depth of from 7 to 8 feet above bed-rock was highly auriferous.

The journey to Willow River is made through Beaver Pass at the head of which is a lake. The Pass itself is filled with glacial gravel and boulder clay. The fall of the Willow River is, perhaps, some 10 to 15 feet to the mile. There are numerous small bars of fine gravel showing a few colours. Here and there are bluffs of an older formation, consisting of gravel, sand and clay, resembling the upper gravel found in some parts of California, and carrying no values. Generally bed-rock is at a great depth. In places Willow Creek splits into numerous channels, most of which are blocked with drift wood; the islands so formed are almost barren

Types of Dredges in Operation.

of gold. Some of these side streams have been worked to a small extent, but there are no indications of past working on the main stream. The superficial gravels are too poor to work, and the rich pay dirt lies at too great a depth. At the head of the streams, where the deposits are shallow, the rich pay-dirt has been reached, and mining in a small way has been undertaken, but 20 miles from the heads of the several streams no bed-rock has been struck, and thus work has been impossible. The bed-rock when found is of soft shale and slate easily worked by a dredger. The benches were worked in the "sixties," and proved very rich. In Cariboo, the length of the working season is about 180 days, and this relatively short season has, of course, to be taken into consideration when determining the dredging prospects. But the writer is fully convinced that a systematic examination of the head waters of the Cariboo streams with a drill, would well repay the cost.

While the writer had no opportunity of visiting Atlin and the other mining divisions in the Cassiar district, he has inspected the principal placer grounds so far discovered in the Yukon. This country apparently affords great potentialities for successful dredging enterprise, but conditions must be carefully studied. Thus, by reason of the extreme shortness of the season, the lack of fuel throughout a large section of the district, in many cases the absence of water, together with the high rate of wages and high cost generally, the value of the ground must necessarily be proportionately greater than in most sections of British Columbia to render operations profitable. Nevertheless, in spite of the many difficulties, reaches on the rivers and creeks have been acquired by companies who have installed on these properties modern and carefully designed plants which are earning handsome returns.

Much of the ground in the Yukon is, unfortunately, frozen to bed-rock, but it thaws readily when the over-burden is removed and the surface is exposed; thus, a sufficient area of thawed gravel may, in many localities, be readily kept ahead of a dredger so as to ensure no suspension of operations on this account. In certain localities, as for example, Bonanza Creek, timber is scarce, and consequently until coal is procurable fuel must necessarily constitute an expensive item. In other localities, however, such as Eureka Creek, timber is abundant. The problem of transportation is also one to be reckoned with, but conditions in this

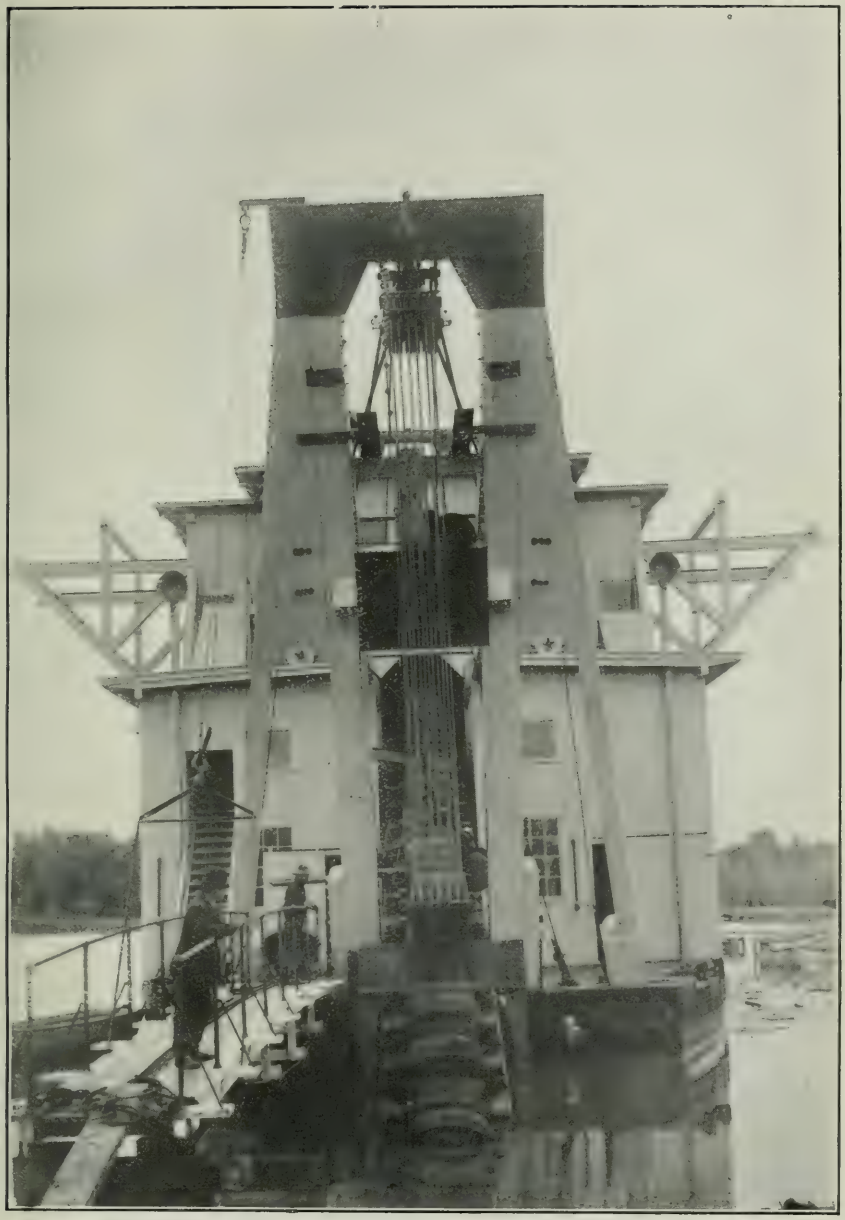
respect are improving every season, since the government is expending large sums annually on road making and is also encouraging the construction of railways.

New and promising possibilities for dredging are also developing in the Omineca district. The conditions here are eminently favourable. The region is undoubtedly rich in gold, and although the lack of cheap and adequate transportation facilities is a present difficulty, this drawback will ere long be removed by the operation through the district of one or more of the new transcontinental railways now in progress of construction.

In passing, it may be noted as strange that in a country so rich in platinum as British Columbia, no effort is made to save the platinum and other precious metals beside gold; this is not universally so, but is generally the case. Perhaps, the reason is that platinum and other precious metals do not readily amalgamate with mercury, and thus are lost when running over the amalgam plate, still they can always be caught after leaving this. Platinum is easily discernible, but some of the other precious metals are not so easily seen, and unless occurring in very large quantities are not noticed, but pass into the tailings.

In the matter of estimating dredging costs, the following notes regarding necessary staff, etc., may be of assistance:

One dredgemaster, one engineer for each shift, one winchman for each shift, one deckhand for each shift, two men to handle fuel during the day shifts, two men around the camp including the cook. When the head lines and side lines have to be shifted, all hands help. It will also be necessary to add a blacksmith to the staff to make repairs in the case of outlying districts. Wages of course vary in different localities. To the above must be added the cost of fuel, oil, and a few contingent expenses. The price of fuel varies with the locality. Dredgers now generally are made to give an output of 4,000 cubic yards per diem, that is in two runs of 10 hours each. The output varies with the nature of the gravel to be dug, and dredgers are being made with much higher capacities. The annual output depends greatly on the total number of hours run, and this of course depends on the stoppages for repairs. The working cost per cubic yard runs under the above circumstances to from $2\frac{1}{2}$ cents to $7\frac{1}{2}$ cents per cubic yard; though in certain localities, where the cost of labour and fuel is abnormally high, the cost is increased.



Bow of Dredge—Showing Buckets.

In conclusion, while, as already shown, the opportunities for profitable dredging in British Columbia are eminently favourable, the mistakes of the past must not be repeated. These mistakes may be attributed to two causes: first, that insufficient care and attention was given to prospecting, and ground not adapted to dredging was, in consequence, selected. Secondly, the dredges employed were far too light in construction and were not designed to suit special requirements. Moreover, the mistake has been made in the past of too blindly copying the designs of plants in use in other countries, on the assumption that a plant in successful operation elsewhere would necessarily answer all requirements. No matter how good the territory, returns cannot be expected unless work is scientifically organized and carried out; but the writer is convinced that the areas above described will well repay careful and systematic examination.

CONSTRUCTION AND METHOD OF OPERATION OF ORE BUNKERS AT SKAGWAY.

By A. L. BERDOE.

Western Branch Meeting, Victoria, B.C., Sept., 1908.

The plant consists of about two thousand three hundred feet of railway track, three feet gauged (of which about 1,800 feet is on wooden trestles), a car bunker, and ore bunker 30 by 72 feet divided into eight pockets, a power station, a wharf upon which are built two loading out towers, and four dolphings consisting of about ten piles each.

The bunker is connected with the dock by means of two double-tracked trestles for Hunt Automatic railways. The structures are built of Puget Sound Douglas Fir, and all piles are creosoted.

The bunkers and wharf towers are housed in and the pockets are lined with Australian Iron Bark.

The whole plant is built on a rocky mountain side with an average slope of about 40 degrees.

The bunker is placed on a point, and in order to secure for it the desired elevation, it was necessary to excavate about 4,500 cubic yards of solid and loose rock. About 3,300 cubic yards additional of excavation of the same class was required to complete the grade for the various tracks.

Nearly a million feet of lumber was utilized in the construction of the plant.

In addition to battering the back piles of the dolphing they are guied with one inch cables to the solid rock along the shore.

The machinery consists of two drums operating return cables for hoisting a Hart convertible copper bottom car from underneath the hopper of the tipple into the ore bunker. The drums are operated by a General Electric Company eighty-five horse power

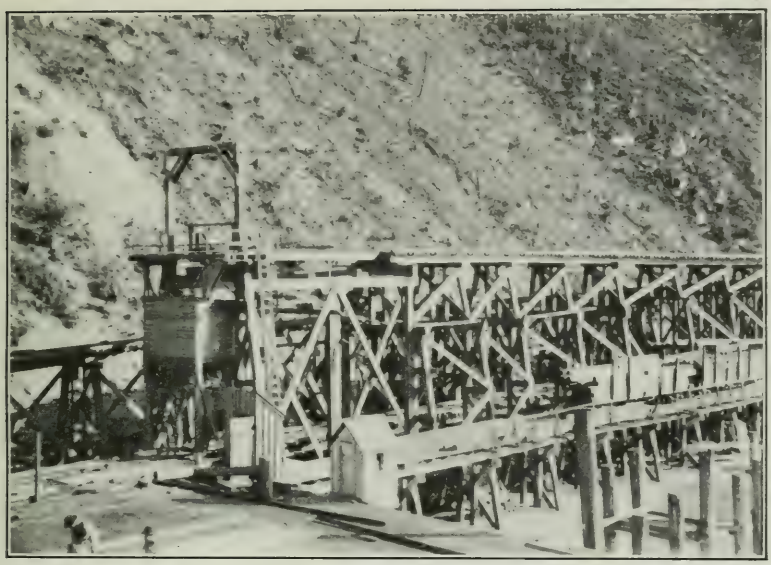


Fig. I

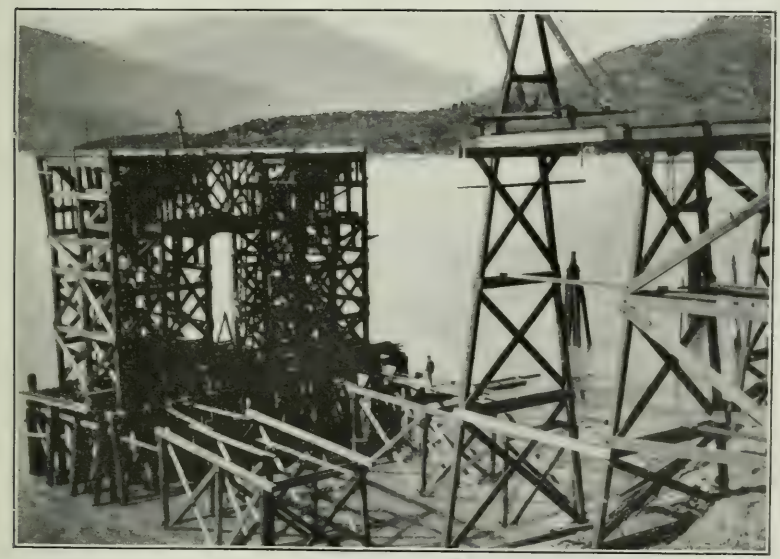


Fig. II

motor, which receives its current from a seventy-two K.W. generator, which is located in the power house at the shops two miles away.

The power house is situated far enough south of the present bunker to allow for the erection of an extension to the bunker, of the same capacity as the present one, namely, 2,500 tons.

The low track is built on a five per cent. grade for about 560 feet. It then runs level for a short distance, after which it ascends one hundred feet on a five per cent. grade. From this point on it runs on a grade of from seven-tenths to one per cent.

The track is of sufficient length of the one hundred feet of five per cent. grade to accommodate eleven loads.

The tipple track leads off from the level portion of the load track and is built on an adverse grade of one-half per cent.

The track leading from beneath the hopper under the tipple to the ore bunker is built on a twenty per cent. grade and splits into two tracks near the bunker, thus giving one track over each series of four pockets in the bunker.

Operation.

The mode of operating the plant is as follows:—

Regular flat or box cars will be used for hauling the ore from the mines and will be pushed up the load track of five per cent. grade, and stored at the south end of the same, south of the one hundred feet of five per cent. track beyond the level grade. They will then be dropped by gravity, one at a time, on to the tipple, where they will be revolved longitudinally until they reach an angle of thirty-five degrees with the horizontal. At this angle, the ore will be discharged into the hopper under the tipple. The car will then be run down the one half per cent. grade to the five per cent. load track and down this to the wharf track. This operation will be entirely effected by gravity. The car dumper will be operated by hand power. Box cars will have an end door for discharging and top doors over trucks for loading.

The ore will next be drawn from the hopper into a Hart convertible car, which will then be drawn up the twenty per cent. grade by means of a cable, and dumped into the ore bunker pocket desired. It will then be drawn out of the bottom of the pocket

into a 5-ton Hunt automatic car, which will run by gravity to the wharf car, where the car will be automatically dumped into a hopper. The ore will then be drawn from this hopper through a telescope shoot into the ship.

The wharf hoppers are forty feet centres and the telescope shoots are arranged to revolve longitudinally along the face of the wharf to accommodate the hatches of the various boats. They are also arranged so that they can be moved up and down in the slides, to make provision for a range of tide of about 22 feet.

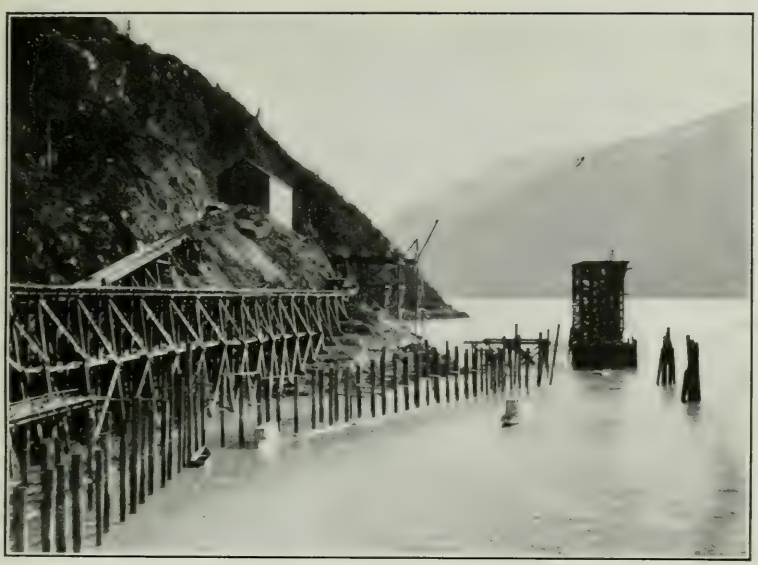


Fig. III

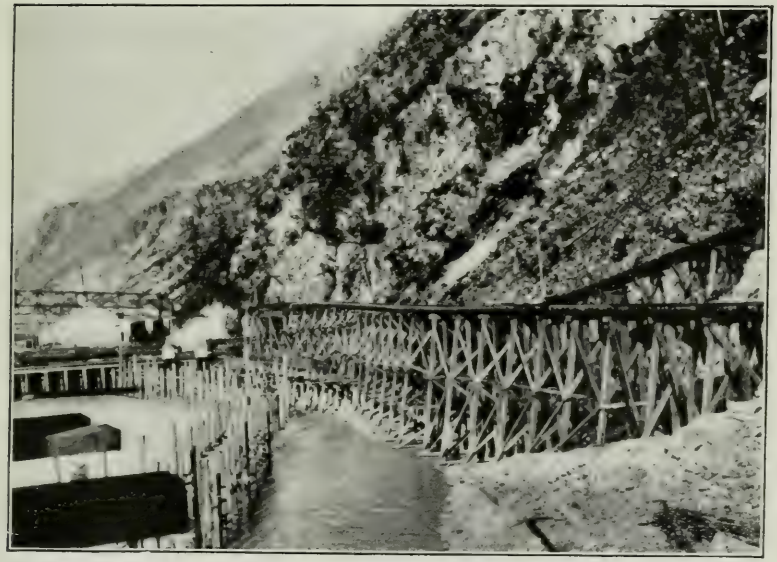


Fig. IV

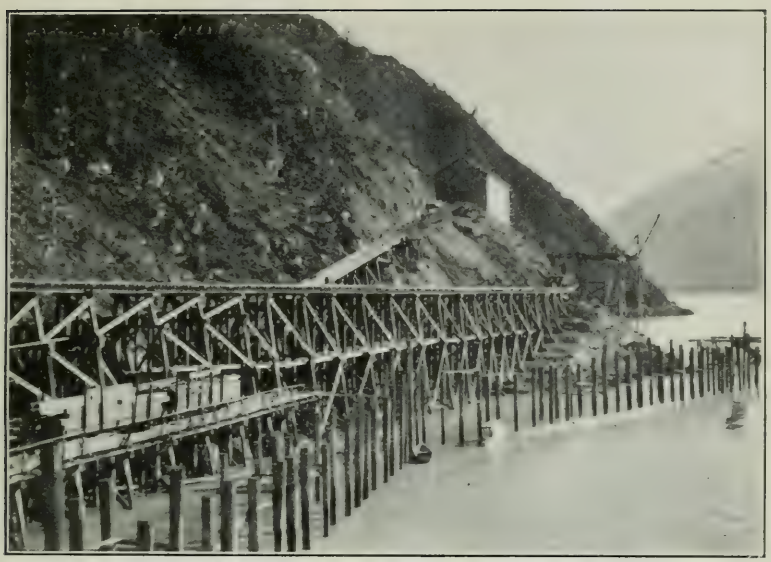


Fig. V

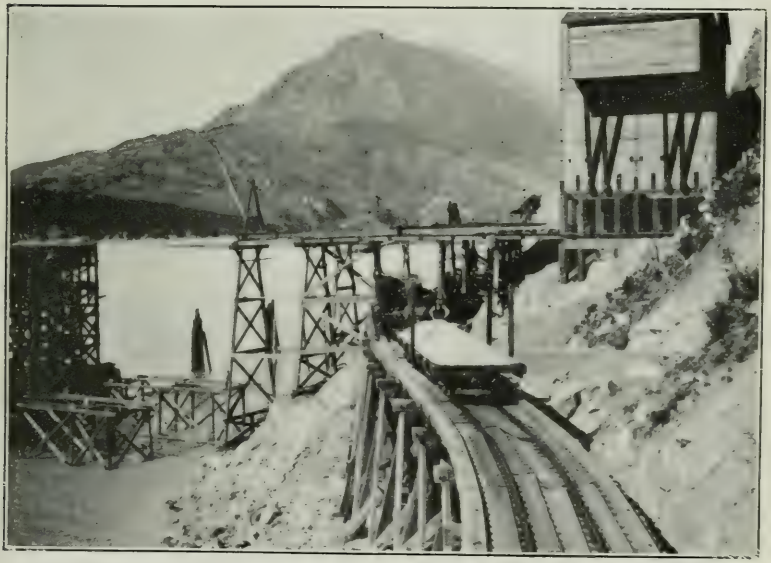


Fig. VI

WANTED—AN INVENTORY OF PROMISING MINERAL CLAIMS.

By R. W. BROCK,

Director of the Geological Survey of Canada, Ottawa.

(Annual Meeting, Montreal, March, 1909.)

In the admirable address delivered by Mr. Hugh F. Marriott, at the banquet given at Vancouver in the honour of the visiting mining engineers last autumn, a scheme was outlined for securing a record of the location of pay grade ore in new districts by means of a system of bonusing the prospector who gives notice of such an occurrence, provided the find passes inspection by a responsible officer. This recalled a suggestion along somewhat similar lines made by the writer to this Institute a decade ago. As this now has the endorsation of so experienced an authority in these matters as *Mr. Marriott, I venture to again bring the subject before the Canadian Mining Institute for consideration.

To provide for the rapid development of the great mineral resources of the country—and over a great area of Canada, mineral development is a necessary precursor of the development of other resources—it is essential that there should be a large number of legitimate prospectors in the field, a large number of well trained professional men to direct operations, and capital. Unless, however, there is a market for prospects, men will not follow a prospector's calling; unless there is a demand for the services of professional men, few will be available; hence, the primary need for the development of the Dominion's mineral resources would appear to be capital. In view of this, much stress is laid nowadays on the necessity of interesting foreign capital in the development of Canadian mining. It may, however, be pointed out that there is capital available in Canada provided the attention of capitalists here were brought to promising discoveries. Once the fact is

*Bulletin Canadian Mining Institute, No. 4, Summer Excursion, p. 295.

established that Canadian capital finds profitable investment in Canadian mines, there will be little occasion to make special effort to divert foreign capital to flow in the same direction, for it will come without invitation.

Canada affords many excellent opportunities for the investment of capital, either in small or large amounts, in mining enterprises. That is a well known fact; but if, for example, the Secretary of the Institute is invited to supply capitalists with specific information in respect of one such opportunity, he would, in all probability, be obliged to generalize, referring perhaps to some district or section as affording favorable openings, rather than to any one property. But if the enquirer, acting on this information, sends an agent to investigate the district in question, it is not unlikely that his time, patience, endurance and possibly his money, will be exhausted in the inspection of mere "wild cats;" and he will leave the country laboring under the belief that there is no meritorious property on the market.

In short, it would be of great advantage to the investor if some certain and expeditious method were provided whereby he might secure information concerning properties which would promise a profitable return on money expended on their development.

On the other hand the prospector, by reason of the nature of his work, has little opportunity of meeting prospective purchasers, and seldom knows how best to bring a deserving prospect to the notice of *bona fide* investors in such a manner as to awake their interest. Managers or engineers of operating companies on the lookout for prospects in their districts have usually experienced too many wild-goose chases to allow a prospector's tale to interest them, even should the latter have an opportunity of relating it. Except, therefore, in times of a "boom," the prospector meets with great difficulty in selling his claim. No matter how good the property, it is, of course, valueless to both its discoverer and the country until placed on a productive basis, which can only be done by the expenditure of capital. The provision consequently of some medium whereby the attention of development companies might be directed to the existence of promising prospects, would be of very real benefit to prospectors. A provision of this sort would be especially necessary and valuable in a country where a majority

of the ore bodies are low in grade, and their development to the stage of producing mines consequently beyond the means or strength of individual effort unaided by capital. Hence, it is apparent that the provision of means by which the man with capital may be introduced to the man owning the promising claim, is of prime importance, looking to the development of our mineral resources.

With this end in view, the writer has advocated the establishment of local centres, such as headquarters of the several Boards of Trades, Mining Recorders' offices, offices of local branches of the Canadian Mining Institute, etc., where a prospector might file a statement containing the following information: his address; an exact description of the location of his property; the dimensions of the ore body, so far as determined; the character and value of the ore; and the terms or price he would be prepared to accept from a prospective purchaser. Of course, the unsupported testimony of the prospector regarding the size or value of his deposit might not be particularly convincing; but if this information was afforded in the form of a certificate from a responsible and disinterested technical man, it would be distinctly valuable to investors.

Meanwhile, copies of the information on file at the respective local centres might be supplied to the several Provincial Departments of Mines, to the Federal Department of Mines, and to the Secretary of the Canadian Mining Institute. It is certain that such information, made readily available, would be invaluable to either corporations or individuals seeking mining investments.

The chief obstacle to the successful operation of the scheme as outlined would, doubtless, be the expense to which the prospector would be put in retaining a qualified man to sample his property. Nevertheless, if once the plan were operative, the certainty of interesting capital in properties would, no doubt, be a strong inducement to prospectors to co-operate in the fullest possible manner. Again, since such lists as proposed would be of great value to mining engineers, they might reasonably be expected to assist the prospector by undertaking, when convenient, the work of sampling claims for an exceptionally moderate fee. Assayers, especially in provinces where they are licensed, might also be employed by prospectors to secure and become responsible for the necessary information in respect of values, etc. The

certificate of a responsible assayer who has a reputation to maintain, stating that he had visited a property on which the ore body was of such and such dimensions; that he had sampled it carefully and found that his samples, representing so many feet of vein, yielded values to such and such an amount, would be testimony of sufficient worth to justify further investigation on the part of a prospective investor.

Such an examination would benefit the prospector in many ways. A technical man when visiting the ground could give the prospector much valuable advice as to the most effective way of opening up and proving the claim. A practical demonstration on his own property would do more for the prospector than any number of text books or mining classes. Most prospectors need and would welcome such assistance. It is pathetic to see a sincere and energetic prospector spending his few hard-earned dollars and the best years of his life doing ineffectual work on his prospect and instead of developing it, rather detracting from, than adding to, its market value. This country cannot afford to have that man's energy and effort wasted. It's far too valuable. It should be directed that the results thereof may be definite and practical in demonstrating the value of a claim.

Again the examination and report would be valuable to a prospector in helping to decide whether his claim was worth further attention or not, and the sooner a prospector can ascertain this fact, the better. If good, he will prosecute the development with greater vigour; if bad, he will divert his energy into new channels.

Not every good claim will yield attractive returns if sampled in the early stages of development, but it will usually have some indications to encourage the prospector to persist. We know, of course, that the faith which removes mountains may sometimes make a mine out of a discarded claim; but the man with that faith is not likely to be staggered by an adverse report.

In short, the prospector will find such a report a good investment. Development companies would find the lists a great boon. Indeed, it is probable that if such lists were available a large number of development companies would be organized to undertake this most profitable business. Proved properties, the product the development companies would place on the market, are the class of investments sought by foreign capital.

DISCUSSION.

A MEMBER:—I am very glad that Mr. Brock has brought this matter forward, as it is one of great importance; and I think his suggestions as outlined are excellent, but I hope he will also offer some suggestion with a view to the prevention of prospects getting into the hands of the stock brokers and promoters of the "wild-cat" class. The prevention of "wild-catting" has been a subject of frequent debate, but it seems to me it is one that the Government should consider more seriously. As matters stand to-day our Governments grant charters to every Tom, Dick and Harry. Three or four men get together and they apply for charters for undertakings capitalized for two million or three million, or five million dollars,—and if it is in Gow Ganda for ten million dollars, and the Government grants them a charter on payment of a small fee. Now, what does that charter mean? It is an act of the Government. The Government by its charter creates paper money. They allow these glib tongued, "wild-cat" promoters to sell worthless stock to the public without restriction. I say this is wrong, and our Government should take more stringent measures to prevent it; while too, the promiscuous granting of charters should not be countenanced.

MR. CLABON:—Mr. Brock stated that the promotion of "wild-cat" schemes is pretty well organized, and by inference he implied that methods for interesting capital in *bona fide* undertakings are feeble, but I do not think that Mr. Brock intended to make that statement. I am quite sure that Mr. Brock and everybody here will agree that it is difficult to draw the line as to what is, and what is not likely to be a valuable property when brought on to the market. The Granby mines, in British Columbia, are one of the most valuable properties in Canada to-day, and I have not the slightest hesitation in saying that a majority of the gentlemen here, at the time that proposition was put on the market in Montreal, would have termed it a "wild-cat." I know that a number of mining engineers reported adversely on that property and stated that it could never be placed on a sound commercial footing. The Granby mines have proved to be a very profitable enterprise, thanks largely to the enterprise and business methods employed in their development and operations.

Mr. Brock advocates the systematic tabulation of data concerning mineral discoveries. I think this suggestion is worthy of the fullest consideration, but, as to the means to be employed I take issue with Mr. Brock. I think that this organization, the Mining Institute, with its local branches, is in a more favourable position than any other institution to receive and disseminate the information in question.

MR. BROCK:—I suggest in my paper that the local branches should undertake this work.

A MEMBER:—And the Boards of Trade.

MR. BROCK:—Boards of Trade also, but I think the local branches and the central body might do something along these lines.

Mr. Clabon's point in reference to the Granby mines is not very appropriately taken, since the fact that the property, when a prospect, was visited by many mining engineers, shows that it was recognized as being worthy of investigation. But my suggestion is that a permanent and careful record be kept of all promising mineral occurrences, so that if they are adversely reported on to-day, they will not be forgotten, but, to-morrow, with the improvement of metallurgical processes, may again attract the attention of mining men. Again by acting on this proposal, prospectors with unknown "Granby's" will have an opportunity of bringing them to the attention of capital.

A property that will make a mine either now or in the near future has usually some "earmark". The fact that value is not sufficiently proven to justify a mining engineer in recommending it as a good investment to his principals does not necessarily relegate the property to the "wild-cat" class. It would be called a "wild-cat" perhaps, if, as an untested and unproved prospect, it were offered to the public as a mine. It would benefit the mining industry if the public were shown the distinction between prospecting, developing and mining, and when asked to subscribe money to a project they were given clearly to understand that the company was a prospecting company, a developing company, or a true mining company. If they had this information, the number of so called "wild-cats" would be very much reduced.

MR. LANG:—I appreciate as much as any man the force of Mr. Brock's argument. Situated as I am, in Cobalt, scarcely a day passes but I receive letters from all over the country making enquiries about properties there. Only last week a gentleman at a distance telegraphed me to know if I would join him in purchasing a property in a certain district at a certain price. I replied that I could not. He then telegraphed me to know if I would advise him to buy it. I replied that I could not do so but recommended that he obtain advice from a reliable engineer. Now, I have been dealing in properties in the Cobalt district since the fall of 1904, and I want to say this: While I will make an examination of a property, I certainly would not dream of buying on my own judgment, but always first secure the opinion and advice of some engineer in whom I have confidence. One of the speakers made reference to "wild-cat" propositions. It is a very difficult matter in our district to determine what is and what is not a "wild-cat". For example not much more than a year ago the Crown Reserve, now one of the important producing mines of the camp, was classed as a "wild-cat". And we have other properties at present regarded with suspicion which ere long may prove to be valuable mines. Thus one cannot with certainty state that any property at any stage of development is a "wild cat".

PROF. DRESSER:—I would emphasize the importance of Mr. Brock's suggestion and add to it only this, viz.: that in the days of the rush to the goldfields in South Africa, the Board of Trade at Johannesburg appointed a committee of mining men to investigate all properties offered for sale. The result of this was that practically no company could be promoted with any degree of success if it failed to receive the sanction of this organization. The effects I believe were extremely beneficial. It has actually worked out in practice as Mr. Brock has suggested, and I have no doubt the records of its proceedings could be obtained and might furnish a very useful and convenient way of formulating a detailed plan along the lines suggested by Mr. Brock.

STUDENTS' PAPERS

NOTE—All of the following papers have been somewhat abbreviated for purposes of publication.

DIABASE AND APLITE OF THE COBALT-SILVER AREA.*

By N. L. Bowen, School of Mining, Kingston.

Discoveries continue to be made in Northern Ontario of cobalt-silver ores, in association with areas of diabase, and especially with veins of aplite in the diabase.

The aplite veins are believed to have been formed by differentiation from the diabase magma. Indeed, the deposition of "valuable mineral" seems to have been so closely connected with this differentiation that a study of the diabase in its many phases should be of interest, both from the scientific point of view and on account of its economic bearing.

Neither the time nor the materials necessary for an extensive study were available; but the chemical and microscopic examination of samples of the diabase and aplite, the results of which are here presented, constitute at least a beginning in that direction.

The differentiation of the diabase, giving rise to more acid and also to more basic types, seems to be of very general occurrence throughout this pre-Cambrian area, being described by Barlow as observed by him in different localities in the Nipissing District;** by Knight in the Montreal River district;† by Hore in the Wendigo Lake district;‡ and by the writer in the Larder Lake.

The first evidence of the change is the appearance of a pink feldspar§ and an increase in the quantity of quartz, which be-

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* Entered for 1909 competition, and awarded First Prize and the President's gold medal.

** Annual Report of Geol. Surv. Can., vol. x, 1897, part i, page 104; also Jour. Can. Min. Inst., vol. xi, 1908, pp 256–273.

† Report of Bureau of Mines, 1907, part ii.

‡ Report of Bureau of Mines, 1907, part ii, pages 135–136.

§ Report of Bureau of Mines, 1908, page 10–11.

comes visible to the naked eye. Since pink is a common tint in the more acidic feldspars, the presence of this constituent in so basic a rock strikes one as rather unusual. By gradual increase in those constituents (quartz and acidic feldspar) the rock may pass finally into a granite. This extreme phase is, however, uncommon, but is noted by Knight at Darby Lake, Whitson township.*

On the other hand a rock containing a considerable percentage of the pink constituent is often developed over comparatively large areas.

Accompanying this change in colour, a change in grain usually takes place, becoming increasingly coarser. This is probably due to the presence during crystallization of a larger proportion of so-called mineralizers in the more acid types.

The texture, too, passes from the ophitic to the granitoid. Obviously then, certain phases are strictly speaking "gabbro"; but the term diabase is used loosely to designate the diabase-gabbro masses in general.

It was desired to study these variations more in detail and, with this in view, numerous sections of the diabase were examined.

A specimen from near the O'Brien shaft, Cobalt, seemed to be fairly representative of the normal phase, and was, therefore, selected for special description.

In the hand specimen the rock is of medium grain, greyish to brownish grey in colour. It shows white feldspar and black pyroxene in about equal amount, and a lesser quantity of mineral with a bronzy lustre. This suggests an orthorhombic pyroxene or perhaps diallage, and giving the rock its brown tone.

A section shows, mainly, laths of feldspar lying in a matrix of augite. Measurement of the extinction angles determines the feldspars as near labradorite. The pyroxene generally fills interstices between the feldspars, but there are certain rounded areas considerably larger than the general grain of the rock and these contain no feldspars. It would appear that the rock magma began to crystallize as a normal gabbro, some of the pyroxene separating first. Then the crystallization of the pyroxene was discontinued and that of the feldspar began and was continued to completion, forming the idiomorphic laths observed. Finally

* Report of Bureau of Mines, 1907, part ii, page 122.

came the crystallization of the rest of the pyroxene, filling the interstices between laths and enlarging the nuclei of pyroxene already separated. The pyroxene which developed in the larger grains shows invariably a lower order of interference colours than most of the other pyroxenes and probably contains a high percentage of the hypersthene molecule. This conclusion is supported by the high magnesia content shown in the chemical analysis (III). Biotite, pyrrhotite, magnetite, ilmenite, and micropegmatite are minor but characteristic constituents.

The rock as a whole is remarkably "fresh" and therefore especially well adapted for chemical analysis as representing the magma. An analysis was, therefore, made and the results are given under III in the following table. In columns I, II and IV analyses extracted, from Dr. Miller's report on the Cobalt area,* are presented for comparison.

TABLE I.

	I	II	III	IV	V
SiO_2	45.20	49.84	50.12	48.06	52.54
Al_2O_3	19.08	18.94	15.70	18.23	15.14
Fe_2O_3	3.64	1.51	1.42	9.57	.85
FeO	14.64	6.40	6.89		10.73
MgO	4.98	7.39	9.50	7.80	5.22
CaO	7.89	10.32	11.30	11.55	6.92
Na_2O	3.32	1.99	2.91	1.87	5.46
K_2O	1.08	1.28	1.07	.27	1.43
H_2O			1.03		
		2.57		3.54	1.76
H_2O			.21		
TiO_2			.55		1.00
BaO			none		
S			.14		
	99.83	100.24	100.84	100.89	101.05

No. I. Is the basalt described by Dr. Miller.

No. II. Is the diabase cut by the basalt also described by Miller.

No. III. Is an analysis made by the writer of the O'Brien diabase described above.

* Report of Bureau of Mines, 1907, vol. xvi., part ii, page 64.

No. IV. Is of another diabase from the Violet claim (Miller).
No. V. Is an analysis by the writer of a coarse phase of the diabase from Pense township.

No. I is seen to be of a more basic type, being an olivine diabase, and illustrates a basic differentiate.

No. II is representative of a typical diabase. The high "loss on ignition" points to rather considerable alteration.

No. IV of the Pense township diabase showing a little of the pink feldspar previously mentioned.

In the hand specimen this coarse grained rock from Pense is rather dark in colour and shows predominant greenish black pyroxene and hornblende, much pale green feldspar and a lesser quantity of pinkish material, presumably feldspar. Pyrite and black iron oxide may be seen on close examination.

Under the microscope are seen feldspars having a tendency to show lath-like form. It is somewhat altered, and twinning is only occasionally noticeable. The augite, nearly colourless, is also somewhat altered. There was also observable a considerable proportion of a long bladed mineral, pleochroic in green colours. The only section available was rather thick and this mineral could not be definitely determined. It is tentatively referred to as hornblende, but the possibility of its being a soda pyroxene is suggested by the high soda content shown in the rock analysis (V) and should not be overlooked. That the mineral might be a soda amphibole approaching arfvedsonite is indicated by the high ferrous oxide. Together with these most abundant constituents there is a considerable quantity of a micropegmatitic intergrowth of quartz and feldspar. The feldspar of this sometimes shows fine twinning lamellæ. A few grains of quartz not intergrown with feldspar were observed, and also a rather large amount of ilmenite with leucoxene alteration and a little pyrite. The micropegmatite fills the last interstices and, where in contact with "hornblende," has resorbed some of this latter constituent. On the outer rims of the iron ores, mica has been produced by a similar resorption. This micropegmatite represents what has been termed pink feldspar in the hand specimen.

The analysis (V) shows a slight increase in silica over III, a decrease in lime, indicating a likely decrease in the anorthite

molecule, a decrease in magnesia, but a striking increase in ferrous iron. The increase in soda is marked, whereas that in potash is slight, so that the ratio of soda to potash is much greater than in No. III.

Another sample of the "diabase" from the Otisse claim, Mickle township, showing a large proportion of this reddish constituent, was found under the microscope to contain a very large percentage of a micrographic intergrowth of quartz and feldspar. A determination of the alkalis in this sample gave the results under III.

	I	II	III
Na_2O	2.91	5.46	6.74
K_2O	1.07	1.43	.566

No. I and No. II are the alkali percentages taken from III and V of Table I. They are placed with No. III for comparison. Here again we note an increase in soda and in this case a decrease in potash.

With increase of the reddish constituent in the rock we have a continuous increase in the percentage of soda. It seems then that this reddish constituent must be highly sodic.

Mr. A. G. Burrows, of the Bureau of Mines,* separated this pink constituent from "diabase" on T.R. 207, Whitson township, and analyzed it.

The table given below is a result of a recalculation of this analysis:

	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	MgO	FeO	Mineral Composition
Orthoclase	2.48			2.70	9.49			14.67 Or
Albite		6.87		11.35	40.00			58.22 Ab
Anorthite			2.08	3.81	4.47			10.36 An
Quartz					13.80			13.80 Q
Pyroxene			.29	neglected		.27	1.6	2.16 P
Sum	2.48	6.87	2.37	17.86	67.76	.27	1.6	99.21
Analysis given	2.48	6.87	2.37	17.86	67.76	.27	1.6	99.21

The figures are not strictly accurate because the presence of magnesia and iron indicates a probable small admixture of pyroxenic material. Some silica and some alumina should have been

* Report of Bureau of Mines, 1907, part ii, p. 122.

allotted to these and this would reduce the figures for anorthite and quartz to a small extent. The results are, however, a close approximation.

This recalculation shows that the material analyzed was necessarily an intergrowth of quartz with one or more feldspars in which the albite molecule predominated to a large extent.

In the microscopic examination of the rock containing this material (by Knight),* given with the analysis, no intergrowth of quartz and feldspar was noted. The intergrowth was probably submicroscopic. Teall traced the gradual passage of an intergrowth of quartz and feldspar in somewhat similar rocks in England, into material in which quartz was not discernible, but which on analysis showed that its presence was indisputable.†

It is more especially in areas where the diabase gives evidence of differentiation into these more acid phases that the aplitic veins, which have such importance from economic considerations, occur.

These aplites have been described by Barlow, Knight, Hore and others, and a brief description calling attention to the more salient points given by these gentlemen is set out in the following:

In all cases they occur in the diabase. Their width varies from less than an inch to three or four feet, the narrower ones being more common; and the length is not more than a few hundred feet. They are very fine grained and usually pinkish to reddish in colour and often possess a distinct "wall" in which case the colour is in marked contrast to that of the diabase.

At other times the aplites have apparently resorbed some of the diabase wall and a more gradual transition from diabase to aplite results. Besides the pink feldspathic material, calcite is usually present either filling cracks or irregularly disseminated, and associated with this is the metallic content. Barite and celestite are sometimes found. The metallic minerals are chiefly specularite, chalcopyrite and galena, together with the cobalt-nickel and silver minerals characteristic of this area.

Numerous sections of the aplites were examined under the microscope, and were found to consist essentially of a panidiomorphic granular growth of quartz and feldspar with pegmatitic intergrowth sometimes developed to a minor extent. Small

* Report of Bureau of Mines, 1907; part ii, p. 122.
† Quarterly Journal, Geol. Soc., 1884, p. 646.

grains of titanite were always found and chlorite, usually in small amount. In nearly every section calcite was detected. This mineral occurs in veinlets ramifying through the other constituents and in larger areas often enclosing irregular, corroded but "unaltered," remnants of feldspars.

It appears that the magma which deposited the aplitic materials was highly aqueous and that the solutions. which resulted after deposition of the quartz and feldspar, attacked the diabase near the fractures in which they were circulating. (Very marked alteration of the diabase especially of the ferromagnesian constituents was observed under the microscope in a sample taken near an aplite vein on 444 James township). In this way the waters may have derived lime from the surrounding diabase and some of this was deposited as calcite in newly opened cracks in the aplite and in miarolitic and other minor cavities. The carbonic acid was presumably an original constituent of the magmatic waters. That the newer solutions exerted a "resorbing" action on the materials of the aplite is shown by the corroded remnants of the aplite minerals.

The microscopic examination of such fine grained material, as that which makes up these veins, leaves some points in doubt, more especially of the nature of the feldspar. Chemical analyses, however, remove all question on this point.

The results of these are given under IV and V of the subjoined table:

TABLE II.

	I	II	III	IV	V	VI
SiO_2	50.12	52.54	-	78.28	58.84	72.33
Al_2O_3	15.70	15.14		12.00	11.24	12.99
Fe_2O_3	1.42	.85				None
FeO	6.89	10.73		1.19	.475	2.50
MgO	9.50	5.22		.37	.35	.97
CaO	11.30	6.92		.29	12.17	1.73
Na_2O	2.91	5.46	6.74	6.89	6.91	7.60
K_2O	1.07	1.43	.566	None	.07	None
H_2O	1.03	1.76		.61	.40	1.09
H_2O	.21					
TiO_2	.55	1.00		.34	.26	.74
CO_2				None	9.84	1.00
BaO	None				None	
S	.14				.13	
	100.84	101.05		99.97	100.68	100.95

I. Is the O'Brien diabase retabulated from Table I.

II. Is the Pense township diabase.

III. Is the result of determination of alkalis in the "red rock" from Otisse claim, Mickle township.

IV. Is an aplite in which no calcite could be detected, from Foster claim, James township.

V. Is an aplite showing considerable calcite; from 444, James township.

VI. Is the granite dike cutting the diabase, on University property, Cobalt.

The mineral constitution of the aplites is so simple, little of the ferromagnesian minerals with variable molecular proportions being present, that it is easily calculated from the analyses and is given for IV, V and also for VI:

	IV	V	VI
Albite	58.38%	58.97 Ab:Or	64.41
Titanite	.83	.63	1.80
Chlorite	3.72	1.59	4.85
Quartz	36.82	16.65	26.78
Calcite	0.00	22.39	2.21
	99.75	100.23	100.05

Obviously they are essentially soda granites.

As stated above No. VI is an analysis of a granite dyke cutting the diabase on the University property, Cobalt. This dyke is described by Dr. Miller and is unique in the Cobalt camp. It has a width of about fifty feet and is fine to moderately coarse in grain and white to pale pink in colour. Under the microscope the rock is seen to consist mainly of feldspar and quartz in allotriomorphic grains with minor areas of micropegmatite. A little green, pleochroic chlorite is present and numerous small grains of titanite. A small quantity of calcite occurs as veinlets and irregular patches possessing the same relation to the other constituents, as does the calcite of the aplites. Dr. Miller suggests that this dyke is similar to the aplites. How much so, is brought out by the above microscopic examination and by the analysis given (No. VI), which on being compared with IV and V shows

a marked similarity. In a late article, Stützer describes this dyke and seems to consider that it was the source of the silver. It has a similar relationship to the diabase as have the aplites; and this indicates that it was, perhaps, closely associated with the silver-bearing solutions. Stützer did not, however, recognize this similar relationship.

A reconsideration of Table II brings out many interesting features. The extreme "acidity" of the aplites IV, V and VI occurring in such basic rocks is worthy of note, as is also the remarkably high soda content and the practical absence of potash, although the potash is rather high in the normal diabase.

A study of I, II and III brings out a progressive increase in soda and in III a decrease in potash. It will be remembered that I is of the normal diabase; II of a "diabase" showing a small proportion of reddish constituent; III of a diabase with this constituent predominating. This red constituent is a micrographic intergrowth of quartz and feldspar and was the last material of the diabase to crystallize. As the proportion of this constituent increases the composition of the rock approaches more nearly that of the aplite. This constituent, which crystallized last in the diabase, must, then, approach the aplite in composition. The conclusion arrived at by Barlow, Knight and Hore, after field and microscopic study, that the aplites represent the *end phase* of the diabase intrusion, is supported by this chemical investigation.

A feature of the diabase which has struck all who have examined it as rather anomalous in so basic a rock, is its content of quartz. The literature of quartz diabases is, however, extensive and it is found that in many parts of the world very similar rocks occur, so similar, in fact, that the descriptions appearing of these latter might easily be substituted, without alteration, for a description of the diabase of the area under consideration. Such a statement may be made of the diabase of the Eastern States which forms the famous palisades of the Hudson described by J. V. Lewis;† and of diabase dykes described by Calkins in the Cœur d'Alène district, Idaho.‡

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* Zeit. Prak. Geol., Dec., 1908, page 511.

† Am. Jour. Sc., Aug., 1998.

‡ Prof. paper 62, U.S.A. S., p. 52.

This is true also of sills, etc., in British Guiana, described by Harrison;* of the Whin sill in the North of England, described by Teall;† and of Keweenawan diabases in Michigan, described by Lane.‡ Numerous other quartz diabases and gabbros more or less similar to that of Cobalt have been described.

It is interesting to note in connection with Harrison's British Guiana diabase that it is strikingly similar in composition and that in nearly every analysis of it traces of cobalt and nickel are found.** The analysis I is tabulated below with that of the O'Brien mine: diabase II for comparison.

	I	II
SiO_2	49.46	50.12
Al_2O_3	16.77	15.70
Fe_2O_3	1.98	1.42
FeO	6.57	6.89
MgO	9.33	9.54
CaO	11.17	11.30
Na_2O	1.55	2.91
H_2O	2.02	1.24
CO_2	.27	
TiO_2	.79	.55
S	none	
NiO CoO	traces	.14
	99.95	100.84

The Pense diabase is compared in the table below with a diabase from Reid's Gap quarry, Middle field, Conn.†† and also with Essexite (III) from Mount Johnson, Quebec:‡‡

* Geology of the Gold Fields of British Guiana, J. B. Harrison, London.

† Quar. Jour. Geol. Soc., 1884, page 640.

‡ Geological Survey of Michigan, vol. 6, page 219.

** Professional paper 14, U.S.G.S., page 335.

†† Professional paper, 176, U.S.G.S., page .

‡‡ The Monteregian Hills. A Canadian Petrographical Province; F. D. Adams, Reprint Journal Geology, April–May, 1903.

	I	II	III
SiO_2	52.54	52.37	48.69
Al_2O_3	15.14	15.06	17.91
Fe_2O_3	.85	2.34	3.09
FeO	10.73	9.82	6.41
MgO	5.22	5.38	3.06
CaO	6.92	7.33	7.30
Na_2O	5.46	4.04	5.95
K_2O	1.43	.92	2.56
H_2O	1.76	2.24	
TiO_2	1.00	.21	
MNO		.32	
	101.05	100.03	

It is seen that this phase of the diabase is somewhat related to the Essexites.

The similarity in chemical composition of the aplites (III) with Washington's Noyangose (I) and Rosenbusch's quartz keratophyre II is illustrated in the table below:—

	I	II	III	IV
SiO_2	78.77	79.36	78.28	62.00
Al_2O_3	12.44	11.54	12.00	22.71
Fe_2O_3	.95	.63		0.85
FeO	n.d.	.63	1.19	
MgO	.02	1.35	.37	.21
CaO	.53	.50	.29	7.12
Na_2O	6.79	6.20	6.89	6.70
K_2O	.24	.51	None	.43
H_2O	.26	.95	.61	1.38
TiO_2			.34	
	100.00	99.50	99.97	101.41

Coleman describes small "grano-diorite dikes" cutting the Keweenawan diabase in the Lake Nipigon iron ranges, and which seem to be quite the parallel of these aplites.*

Certain dikes described by Duparc from a Russian locality† also show some similarity, in that they are acidic dikes cutting a basic rock, in this case a pyroxenite. The analysis IV of one of these, taken from the article referred to, shows that they are

* Report of Bureau of Mines, 1908.
† Arch. sc. phys. et nat. Geneve, 1902, 6 Févr.

characteristically more basic which, is, perhaps, to be expected in the more basic rock.

A few points concerning the diabase, in its more general relations, as presented at different points from the Cobalt district to the Abitibi country, are probably not out of place. It occurs as dikes and sills cutting all the pre-Cambrian rocks of the area; in the Archæn complex (Keewatin and Laurentian) it is especially apt to form dikes; in the proterozoic sedimentaries (Lower and Middle Huronian) more commonly sills, conforming more or less with the bedding. The Ordovician sedimentaries are shown to be later. It has approximately the same age as the Sudbury norite, the sills of the Lake Superior country, the dikes of the Rainy River country and the sills and dikes which intrude Proterozoic sediments in British Columbia and Idaho. Also, in the area north of Montreal described by Adams, the latest of the pre-Cambrian rocks is a similar quartz diabase. The general prevalence of this kind of igneous activity both in the east and in the west at this period is noteworthy. The diabases of Michigan, too, are quite similar, so that it seems that this whole area in the east constitutes a petrographic province. A study of the mineralization produced by the flows associated with the Keweenawan diabases in Michigan and by these intrusives themselves in other parts of the area brings out interesting interrelations:

Michigan	Copper	(Silver)	(Native)
Thunder Bay		Silver	(Native, Sulphides, &c.
Sudbury.	Copper		Nickel (Sulphides)
Temiskaming	(Copper)	Silver	Nickel Cobalt (Arsenides.

THE CALEDONIA COAL MINE, DOMINION No. 4,* GLACE BAY, C.B.

By Eugene P. Cowles, McGill University, Montreal.

The Caledonia Mine is situated within the town limits of Glace Bay, N.S., and about half a mile from Caledonia Junction, on the Sydney and Louisburg railway, owned by the company. This again is about fifteen miles distant from Sydney, and twenty-five from Louisburg. In the summer much of the coal is shipped to docks at Sydney to be loaded on vessels for Montreal, Boston, etc.; in the winter to Louisburg, which is a less convenient port in summer, and to the banking station at Dominion No. 2, where it is stored until the shipping season opens. The mine was opened in 1866 by an American company and was acquired by the Dominion Coal Company in 1893.

The Phalen seam of the Glace Bay basin is worked in this mine, as well as in five other collieries, the coal being mined from both land and submarine areas. With one exception, to be mentioned later, there is complete absence of faulting or dislocation, although undulations and local changes are met with. Phalen coal is a rather friable, fat bituminous coal, specific gravity 1·28 to 1·30, of high heating value, a good coking coal and capable of yielding profitable by-products.

The seam in the Caledonia areas averages about eight feet in thickness, true pitch N. 30° W. with a 12 per cent. slope. The roof coal, on the west side of the mine, is very clean, but, on the east side, it is necessary to leave more than a foot of coal because of the roof and of the impurities in the coal next to the roof.

A fault was encountered in the submarine section in No. 8 east low level, east deep, in August 1908. Soft stone and clay were first struck at the roof and the seam of coal disappeared at a

* Entered for 1909 Competition and awarded second prize.

distance of 20 feet. The same fault was also met with in the main level; and when the roof was investigated 14 feet of coal was found, proving to be a reverse overlap fault. In No. 9 east, when the fault was reached, the trouble was much less, and it was only necessary to grade the level slightly. Fig. 13 illustrates a section taken along No. 8 east level, and is a plan of main and low levels showing the approximate line of fault. To the writer's knowledge no similar fault has ever been found in the Phalen seam.

Coal is mined in this pit by the room and pillar method. In the newer workings three deeps are driven, each 12 feet wide having pillars of about 30 feet between them; at every 500–600 feet, levels are broken off. The faces can be more easily ventilated when all three levels are driven together down hill, but, on account of water, two only are generally driven at the same time, and the third is driven uphill in sections. By leaving a rib of two or three feet of coal in this deep (wherever necessary) sumps are formed into which the water from the face is pumped by the sinking pumps. The distance between cross-cuts depends largely on the difficulties of ventilation; they are often 100 feet apart.

Levels are broken off from the back deeps. There are three levels on each side, and a cross-cut between the main and back deeps opposite the main level serves as a landing.

On the east side of the deeps a pair of headways are driven parallel to them at a distance of 150 feet; the rooms are broken off from these headways, thus leaving a substantial pillar to support the haulage way.

The counter level (the one above the main level) as it is chiefly used for ventilation purposes, is only driven as far as these headways, and to about an equal distance on the west side. The main and lower levels are simultaneously driven to their respective barriers on a slope sufficient for drainage; rooms are broken off the inside headway, and also off the main level as it advances, and are driven to the rise.

Since the direction of the barriers on the west side of the deeps are not parallel to the room course (see plan), barrier headways are driven parallel to the barrier, on the west side of both deeps, and rooms are broken off the outside of these headways, thus saving the triangular block of coal which would otherwise be lost.

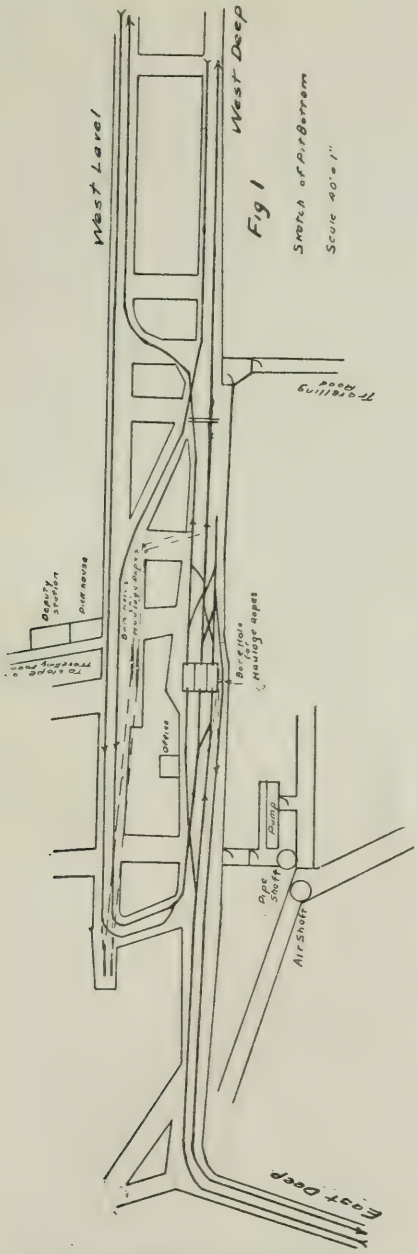


FIG. I.—Sketch of the Pit Bottom.

Rooms are driven up to within about 20 feet of the lower level above, with pillars 25–40 feet between them, the pillars being wider, in the submarine sections. Cross-cuts 12 feet wide are driven from room to room, about 60 feet apart; the third cross-cut is driven on a level course and at the same distance from the level in each room; this makes a counter level on which coal is hauled from several rooms.

In No. 8 west level, west deep, downhill rooms are being driven. Cross-cuts between these rooms will complete the barrier headways from No. 9 west as soon as these have been driven to the outside rooms of this downhill section. It is expected that the cost of narrow work will thus be reduced.

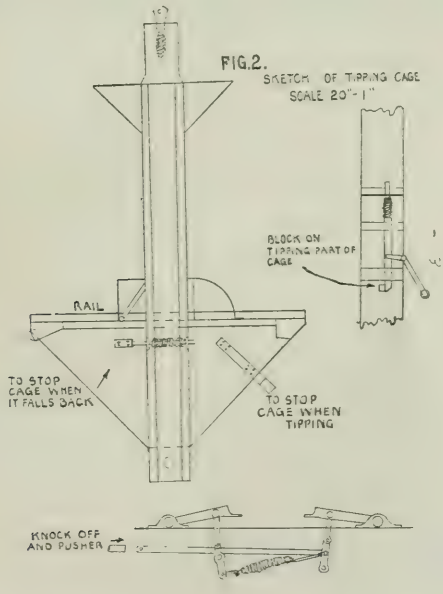
All rooms are driven on the cleat of the coal, that is to say, with a bearing of about S. 7° 30′ E., which makes them about 50° to the level; but in order to mine the coal more economically it is proposed to drive headways every 500 feet, with rooms on level course in the submarine areas.

Figures 10 and 11 are sketches of room sections and show the track arrangements. The rooms in land areas, where pillars are to be withdrawn, are from 16–25 feet wide; in submarine areas they are driven the full 20 feet permitted by the regulation. In accordance with the provision of the present law the pillars are left, the pillar width depending on the cover as provided in the following table:

"Regulations by Government Inspectors of Mines, Sept. 10, 1904, regarding submarine pillars and rooms below 180 ft. limit."

Cover in feet.	Room.	Pillars.	% Coal left.
200	20 ft.	30 x 75 ft.	51
250	20 "	30 x 75 "	51
300	20 "	34 x 75 "	54
350	20 "	38 x 75 "	56
400	20 "	42 x 75 "	58
450	20 "	46 x 75 "	60
500	20 "	50 x 75 "	61
550	20 "	54 x 75 "	63
600	20 "	58 x 75 "	64
650	20 "	62 x 75 "	65
700	20 "	66 x 75 "	66
750	20 "	70 x 75 "	67
800	20 "	74 x 75 "	67
850	20 "	78 x 75 "	68
900	20 "	82 x 75 "	69
950	20 "	86 x 75 "	69
1000	20 "	90 x 75 "	70

The machines in operation are the Yoch, Improved Yoch, Ingersoll No. H4, and the H and H. Either size pick can be used by changing the socket. The picks are 2 inches in diameter, $2\frac{1}{4}$ inches across the points and about 1 foot long. The air for the machines is supplied by $1\frac{1}{2}$ inch pipe in each room, the pressure being 60–70 lbs. per square inch. They are operated on 3 x 10 ft. tables, resting on a low horse at the back end and on the floor next the face. The cut is 5 or 6 feet deep, 4 to 5 feet wide, and about 15 inches high in front, slanting back to the width of the pick. Four or five cuts are made to a room, and seven cuts is considered a good day's work. The machine runner is paid by the ton, and is required to find his own powder and to pay his helper, whose wages are usually $1.65 per day.



The drilling and shooting in the rooms is usually done by the loaders, who use hand drills, but in narrow work the machine runner does his own drilling with an air drill. Three shots are needed to a face unless it is sheared, and as the plug shot shatters the coal, shearing the face up the centre and using two shots would be desirable, but owing to insufficient pressure no shearing

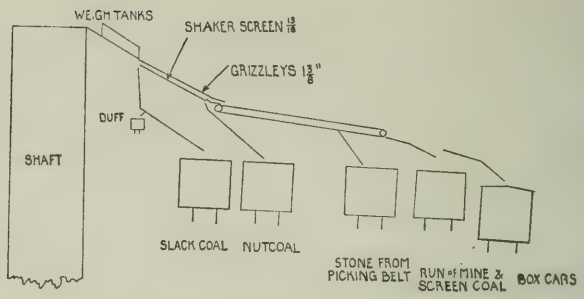


FIG. 3.
SKETCH SHOWING ARRANGEMENT OF SCREENS, CARS, ETC.

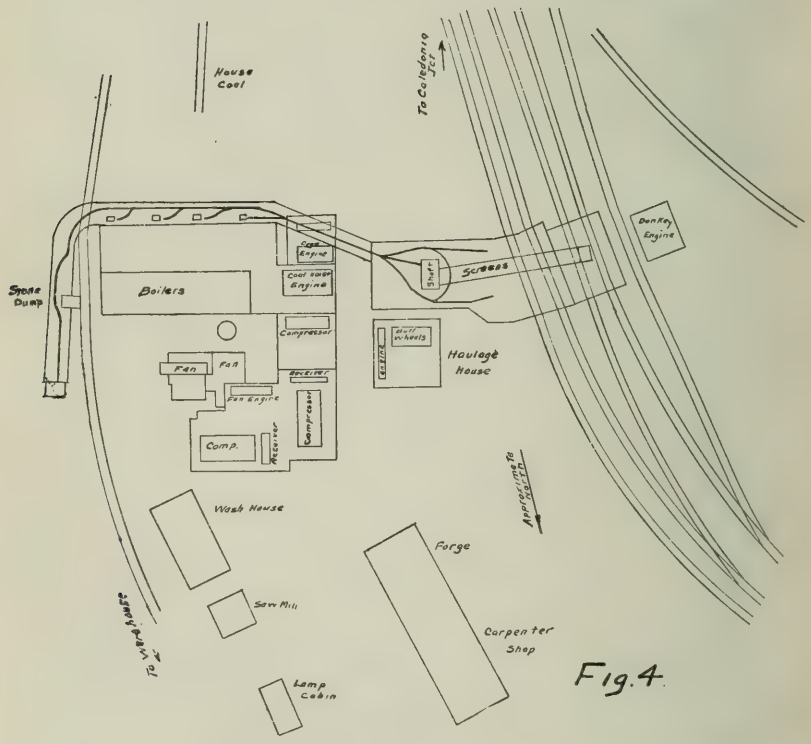
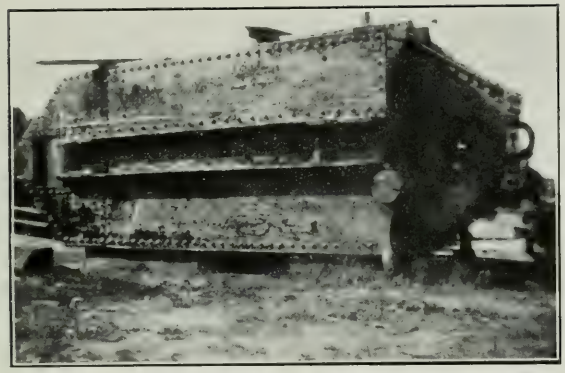


FIG. IV.—Sketch of Buildings and Yard.

3 24

Head Frame, Caledonia Mine.

Water Hoist—Tank discharging, Caledonia Mine.



Water Hoist Tank, Caledonia Mine.

Water Hoist, Caledonia Mine.

has been done in Caledonia for about two years; it will probably be resumed in September, 1908. Jeffries' air drill and shearing machine are in use.

The roof coal is left in the east deep as it is somewhat dirty, but in the west deep all the coal is taken out. When the roof coal is to be left, the holes are bored under a parting in the coal, about one foot from the stone, otherwise the holes are slanted up through this parting. Shooting is done with "Bulldog" powder in all parts of the mine except No. 8 east, east deep, where "Excellite" powder and a battery are used. All shooting must be done by company shot-firers, who are first supposed to test the roof, see that there is no gas at the face, and that the holes are properly stemmed.

Coal is mined in parts of the west deep by hand pickmen, on a parting about 18 inches from the pavement, and the law requires that in this work sprags shall be used. Machine cut rooms are only spragged at a turn in the face after one or two cuts have been made.

The best method of drawing pillars is to start at the inside as soon as the rooms are finished and take out the level pillars at the same time. By adopting this course the road will always be dry and even, as a crush never comes on the pillars supporting the level.

The length of time that a room may stand before the pillars are started depends greatly on the condition of the roof. They are often left for as long as two years, but whenever they are left for that length of time it becomes necessary to clean falls, re-timber and lay new road. At the present time pillar men are waiting for rooms to be finished to start drawing the pillars and so these troubles are not encountered.

The method of drawing is as follows:—The stone is broken on the cleat, S. 82° 30 W., when pillars are drawn from the inside of east side levels, but on the west side of the deeps it is broken on a line about 60° to the cleat. The inside pillar is started by driving a cross-cut about 30 feet from the top and drawing this uphill. If a fall occurs, which is usual, the pillar is again started about 30 feet below, and the next outside pillar is commenced; but if there is no fall the pillar must be drawn on downhill until one comes. Ordinary pillars are about 60 feet long and can be

split in the middle and worked in two halves, but where a pillar is longer it is cut in two places, as 30 feet is about as much as can be worked successfully. Each pillar is kept in this way about 35 feet in advance of the one outside. Nearly all the pillars are drawn uphill. For example, in No. 7 west, west deep, seven out of eight were drawn in this way. The chief advantage of drawing down seems to be that there is no chance of losing a stump. The loss of a stump, of course, is followed by a crush on the pillar below, in consequence of the stone not breaking in a dome. If pillars are drawn either more or less than 35 feet in advance of each other, there is likely to be a crush, and it is often necessary to double shift some pillars to maintain this distance. A very thick pillar is sometimes taken out by drawing half the width first and then the remainder. The method used to stop a crush is to build heavy blocking in the cross-cut below and rush out the coal above as quickly as possible.

Warning of a fall is given by the timbers crushing and breaking. There is no parting near the pavement on the east side of the mine, and the pillars are mined in the middle where they crush most easily.

The rate of pay for work is in accordance with the decision of the Conciliation Board of 1907, composed of representatives of both the company and the men. The Board slightly modified the scale proposed by the company, agreeing on the following prices for mining in the Caledonia Mine. These prices hold to December 31, 1909:—

PRICES FOR MINING (PER TON).

Machine Cut Rooms.	West.	East.
	c.	c.
Cutting	11·5	13
Loading	14·5	15
Shooting	8	9
Shearing	4	4
Cross-cuts. 12·5c. per linear yard in addition.		

Machine Narrow Work.	West.	East.
Deeps	41·5	47
Headways	40·5	45
Levels	40·5	45

Hand Mining.	West.	East.
Rooms	49	51·5
Cross-cuts (addition):— 32·4c. per yd. for 12 ft. cross-cuts to 74·2c. per yd. for 30 ft. and over cross-cuts.		
Pillars	43	45·5

NOTE.—There are slight increases in some of the above according to sections.

POWDER PRICES.

Bulldog powder	13.5c. per lb.
Excellite powder	16c. "
Rippite powder	20c. "
Detonators	2.5c. each.

The timbering at the bottom of the shaft is done with heavy squared timber. Props and booms of large unfinished timber are used in the main deeps, and smaller props are set on the booms where the roof has fallen. Machine runners or loaders keep the levels, headways and rooms timbered well up to the face with booms or props and cap pieces; these light timbers are about 5 to 9 inches in diameter; 25 cents is paid for each boom. Shiftmen renew timbers in levels and rooms where coal is being hauled. If a whole level is to be re-timbered it is generally done by contract; in one instance the price was 40 cents a yard with a boom every 4 feet. In all cases the company provides the timber and delivers it where it is to be used.

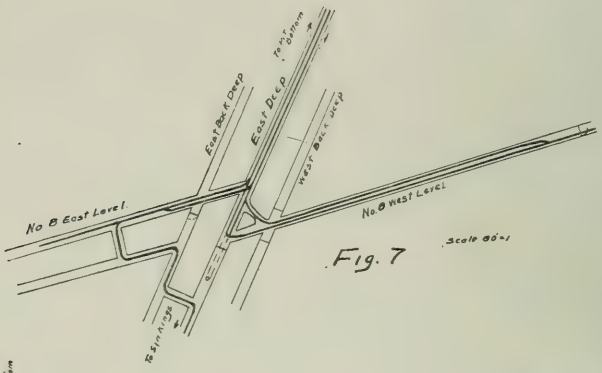
Compressed air is supplied to each side of the mine by 8 inch pipe lines going from the receivers in the compressor house down the pipe shaft.

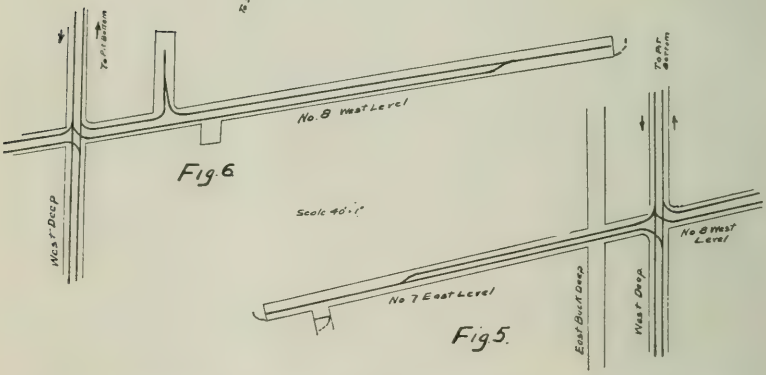
At one time the pressure in Caledonia became so low as to necessitate the laying of a line of 6-inch pipe to this colliery from Dominion No. 3. This pipe enters by one of the slopes and joins the 8-inch line in the west deep. This air was not being used in the summer, but was expected to be required when shearing was started.

The endless haulage system is in use, horses being employed to haul the coal from the room faces to the landings on the deeps.

There is one haulage in each deep and one in the west level. The No. 2 deep was driven when the output in west deep became too heavy. (See plan).

The west deep is now approaching Dominion No. 2 barrier, and when the deeps have been driven to No. 9 east level, or one lower than it is at present, the rope will be turned in on this level. The average output of this deep is between 500 and 550 boxes per day.





The east deep is straight from the pit bottom to No. 10 east and west levels, the rope only goes to No. 9 landing. The output averages about 575 boxes per day, but it has been as high as 775, and as the whole haul is on a 7 to 8% slope, more power is required than for the west deep. This deep is expected to go to No. 20 landing, and will become too heavy for one rope, so an auxiliary haulage driven by an electric motor will be used below No. 10 landing. The deep will be submarine below the latter.

A self-acting haulage rope will be put in the submarine headway from No. 9 to No. 5 east levels. This is necessary, since Nos. 6, 7, 8 and 9 east levels will all be driven to the barrier of Dominion No. 6, and some of these levels are already far from the deep. The rope will be $\frac{7}{8}$ inch diameter, and will have a grip wheel with brake at the top; the wheel has been ordered from England.

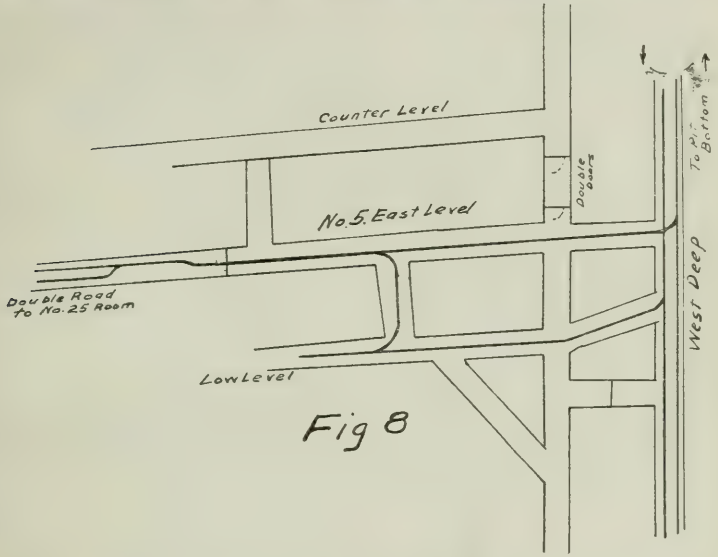


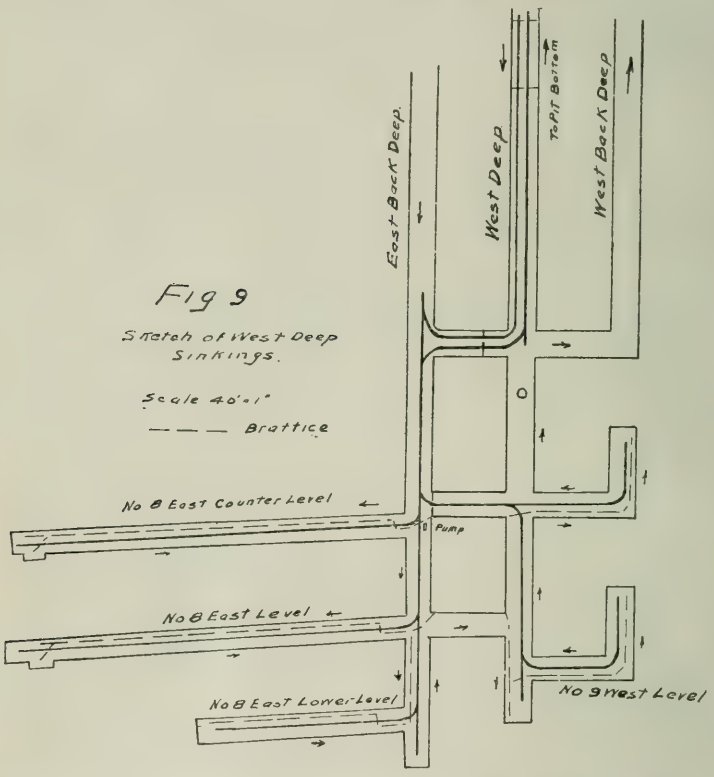
Fig 8

The endless haulage ropes are all $1\frac{1}{8}$ inch diameter, 6 strands, with 7 wires in each, wound on a marlin core. Some of the steel rope is imported from England, and some of it is manufactured and supplied by the Dominion Iron Wire Co., Montreal.

The ropes run on iron and wooden rollers which are approximately 25 feet apart. Guides in the form of wooden blocks have been placed at odd distances, especially on the empty road where the rope is apt to be shoved off the rollers; they are being replaced by bottle-chocks. These are used on all curves; they cost $3.30 each. The full road curve at the top of the east deep has 105 of these bottle-chocks.

The tension wheel at the end of each rope is on a tram which runs on its own track. The tram is held by heavy timbers let in to the pillars and roof props. The back balance is on a rope attached to the tram and running through a block in the roof.

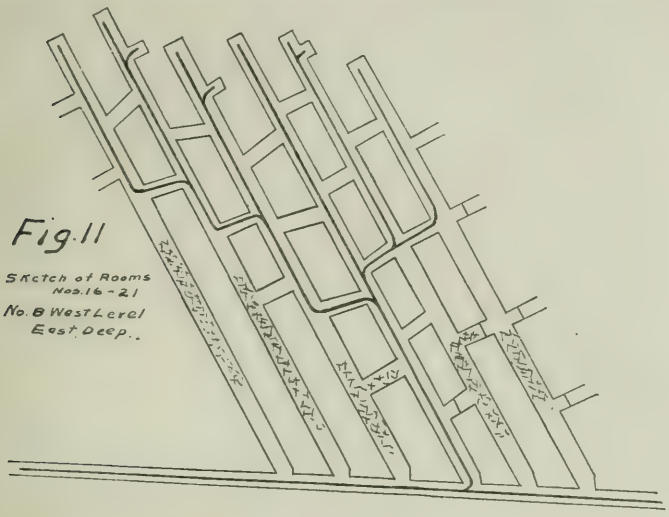
The balance weighs about one ton and keeps the rope tight on the tension wheel at all times. The ropes are turned on 7 foot pulley wheels at the pit bottom and go up bore holes to the bull wheels in the haulage house. The empty ropes run from the bull wheels

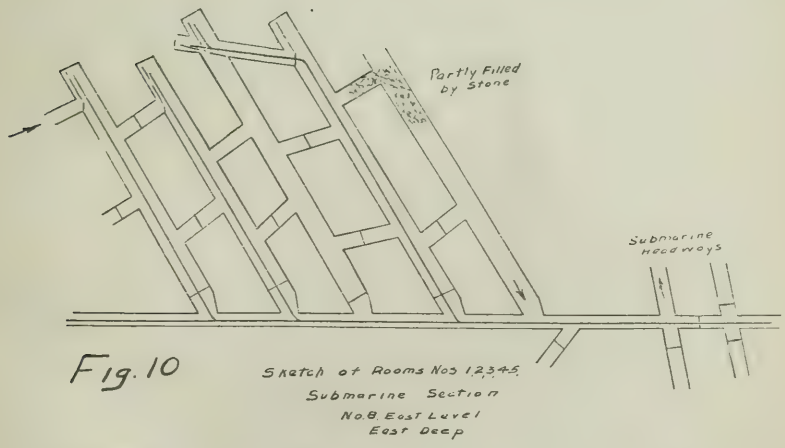


to tension wheels with back balances weighing from one to two tons. The ropes run at about $1\frac{3}{4}$ miles per hour. A 70 foot splice with six tucks is made when the rope is repaired.

All the levels in the east deep are driven nearly opposite one another, that is, the west main level is about 40 feet below the one on the east side. This makes an opening only on one side of the deep and makes landing tending easier than where both levels are directly opposite. The east side landings are all the same, with empty and full roads side by side, and sufficient grade on the latter for the boxes to run out. Fig. 7 shows the lowest landings, No. 9,

east and west. The west side landings on this deep are about the same, with the difference that there is always a block of coal between the ends of the full and empty roads; this is to get a suitable curve on which to run the empties off the deep.





On No. 7 east and No. 7 west landings there are spare road drivers hauling with two horses three boxes at a trip. Narrow work and room coal is being hauled from five of the six levels on the east deep, and pillars are being drawn on two levels.

The deeps have been driven to No. 10 landing, which is just at the shore line, but the levels have not been started.

Some method of turning the boxes is necessary at every landing in the west deep, since the front of the box must necessarily be the door end both going down and coming up the deep. On Nos. 4, 6 and 7 east landings the full turn is laid down the deep, the box runs out and is spragged while putting on the grab; this is shown by the sketch of No. 7 east, Fig. 5. A left hand turn is used at No. 5 east for turning the empty box, Fig. 8, and at Nos. 7 and 8 west a back hand turn is used to turn the full box, Fig. 6; the box is hauled up into the turns and runs out on to the deep when unhitched. Fig. 9 shows how the coal is hauled from the faces of the levels and deeps.

There is more pillar work in the west than in the east deep. Four of the six levels have room and narrow work and two levels have pillar drawing only.

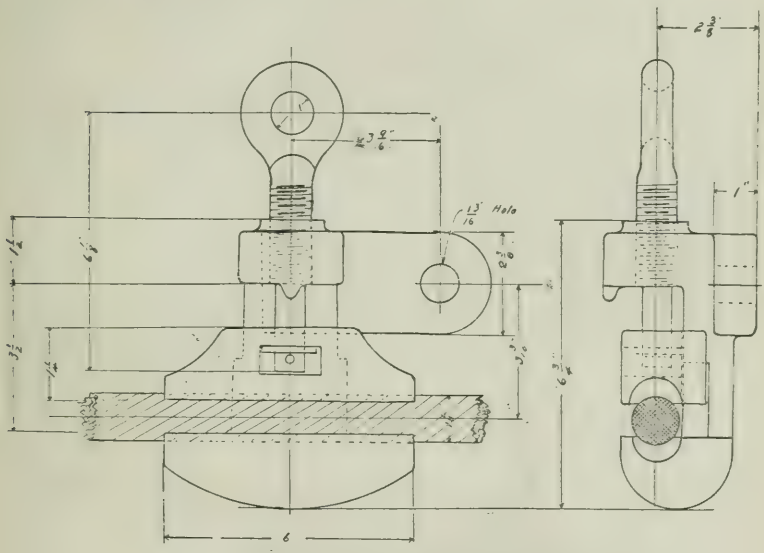
No. 5 east has a double road to No. 25 room; coal is being hauled from inside rooms and a few pillars; these rooms are being driven with hand picks and are nearly completed. Pillars will be started from the inside when the rooms are finished, and the level pillars will be drawn at the same time. The double road was laid when there were ten drivers on this level; it is the only one in the mine. The work in the sinkings is extensive, levels on both sides of the deep and the three deeps are all being driven. (Fig. 9.)

The track gauge is 23·5 inches and 30 lb. rails are used in the deeps. There is a spring switch to throw runaway full boxes off the road above each landing, wooden switches strapped with iron are used on the landings themselves, turns are 6 feet from point to frog.

The boxes are 7 feet 2 inches by 3 feet by 2 feet inside dimensions, and the average weight of coal is about 3,000 lbs. New boxes have 6 inch. side boards on the sides and back end, which increases their capacity about 300 lbs. A drawing of a grab is shown. The wrought iron bar is $\frac{3}{4}$ inch in diameter and 20 inches long, but is bent to escape the bottle-chocks.

There are stables on each side of the mine. The ones in the west deep have 35 horses and have a slope to the surface. There are 49 in the east stables and the slope is at the pit bottom about 1,000 feet from them.

Roadmaking is all done by contract, two men taking a section of one or two levels. The men are paid $0·017 per ton of coal hauled in each section, and for this pay they are required to lay rails in levels, headways and rooms. The weight of rails in levels is 30 lbs., and in rooms 18 lbs. In addition, 22c. per yard is paid for extra work, such as a double track in rooms, a turn through a cross-cut below the third, relaying rails in rooms when pillars are started, etc. 11c. per yard is paid in some cases for taking up track, 25c. per yard is paid in the deeps.



—CRAB FOR ENDLESS HAULAGE—
—General Arrangement—

The boxes enter the cages from the east side, east deep coal on one track and west deep and level coal on the other. The required slope was got by driving the east deep through rock at the curve about 260 feet from the shaft, so the grade is roughly 3%. The west deep and level full roads meet in the west level, and the grade is obtained in the cross-cut where they emerge on the pit bottom. The west deep full road crosses over the west level empty road, at a point about 140 feet distant from the shaft.

The cages dump to the west side, so the empties for the west level and deep go on the rope with the door end ahead. The east

deep empties are shunted back through a cut beside the shaft, so their door ends are behind going down the deep.

There is a slope for horses or emergency use from the pit bottom to the outcrop. There is also an underground manager's cabin, deputy station and tool houses. A sketch of the pit bottom shows track arrangement, etc. (Fig. 1).

The shaft is 12 x 16 and 180 feet deep; in three compartments. The man cage goes to the first floor of the bankhead to hoist fire coal, stone, etc., which are dumped from the trestle, and the coal hoists tip at the third floor. There is very little timbering in the shaft; in the coal cage sections are placed 6 x 10 inch buntons 8 feet apart, $4\frac{1}{4}$ inch spears at the sides for guides to the cages, and light 4 x 4 inch spears at the back of the shaft on which the rollers of the cage run if the lock fails. A heavy board partition separates the coal hoist and the man cage divisions; the man cage is provided with four rope guides.

Three sketches of the automatic tipping cage are shown in Fig. 2. The empty box is released as the full one goes over the "knock off" and is pushed out by the full box. A roller on an arm strikes a wooden wiper near the top of the shaft. This unlocks the cage, and it rolls out on the spears, which curve back at the top; the cage is started by the springs. There are hooks on the sides to catch the framework if the cage is hoisted too far, and the springs mentioned break the jar as the cage falls back and locks.

A hook catches the door of the box as the cage tips and the coal falls into the weigh tanks, which are connected to Fairbanks dial scales reading to 25 lbs. Weighing is undertaken by a weighman employed by the company and a check weighman paid by the men; a boy takes off tallies, raps down the cage and calls the numbers to the weighmen. The two tanks are opened and closed automatically by chains fastened to the pulley wheel shaft. The coal falls on to a gravitation screen 18 feet long, $1\frac{3}{8}$ inch between grizzlies; from this screen it goes over the picking belt and into the car as domestic coal. The stone from the two picking belts averages about 3 tons per day. Nut coal is made by passing the material through the grizzlies and over a shaker screen 13/16 inch mesh. This nut coal may be conveyed out on the picking belts by closing a trap in the chute at the end of the shaker screen. The material passing through the shaker screen is "slack".

"Run of Mine" is made by placing iron plates over the grizzlies. (See diagram, Fig. 3).

Cars are started out from the bank by a donkey engine.

The output averages about 11,700 tons per day.

Until March, 1908, all the pumps were operated by air; but the pressure being inadequate it was decided to install three large electric pumps, of which two are now in place, one in each deep, with bore holes to carry the discharge and the wires.

A steam hoist, which was used previous to this for all pumping, will now be utilized for acid water in the east deep and for removing water not pumped by the west deep electric pump. The sump is in No. 3 east, west deep, and the shaft is 180 feet deep. There are two iron tanks of 800 gallons' capacity. The rate is 3 tanks per minute, and the plant is maintained in continuous operation. This has proved to be a very satisfactory and cheap method. During the year 1907 the cost per 1,000 gallons, was only $0·0312 inclusive of fuel, repairs and wages. 83,200 tanks were hoisted in May, 1907. The plant was in continuous operation, except for a 19 hour stop for repairs to a broken crank pin. A spare tank is always kept in reserve. It may be mentioned that one-third the cost of this plant is defrayed by Dominion No. 3, part of whose mine water flows into No. 3 east sump.

The lodgment in No. 9 east for the electric pump was made by building concrete dams at the bottom of several outside rooms; the water is discharged from the pumps in the back deep and flows in through a slant (see plan). The pump is a 500 gallon Macdougall Turbine of three stages, operated by a 100 H.P. Westinghouse motor, the discharge being of 10 inches diameter and 450 feet to the surface. It has not proved very satisfactory, owing chiefly to the acidity of the water. After the first 70 running hours all the interior fixings required to be replaced at a cost of $250, and after 100 hours' further working, again repairs became necessary. It is now operated for about seven hours daily and appears to be giving greater satisfaction.

A 1,000 gallon Northey is installed at the pit bottom, discharging by a 10 inch pipe to the surface. This pump is used in spring or fall during rainy weather; the water enters in from the slopes and the outcrop.

Caledonia is not regarded as a gaseous mine, but gas collects where the air is slack as soon as the face is driven much beyond the brattice. On account of gas in No. 8 east level, east deep, shots there are fired with "Excellite" powder which gives little flame, an electric battery being employed. A hole was formed in the roof by a fall of rock at the face of this level, and consequently the gas which accumulates is driven out by a jet of air. In 1899 an explosion, supposed to have been caused by an open light, resulted in eleven fatalities. The mine was flooded and the west deep, which started from the pit bottom, was abandoned.

Ackroyd and Best's safety lamps were installed February 28, 1906.

Air to ventilate the working faces of the mine is maintained in the air course by double and single wooden doors and brattice stoppings and turns. There are double doors in the east back deeps, which are used as travelling roads, and single doors on the landings inside the back deeps. The face of a level can often be driven as much as 40 feet from the brattice where the air is good; but in the case of a headway or a deep being driven uphill it is necessary to keep brattice within a few feet of the face. The method of ventilating the sinkings and new levels is illustrated in Fig. 9, the arrows in the plan indicating the passage of air down the east back deep, around the faces and up.

When a room has been driven about 30 feet from the level, brattice is placed across the latter and up the room, and when the first cross-cut is passed, a brattice door is placed across the room end, and the turn reaches from the cross-cut to the face. The air always travels around the faces through the upper cross-cut.

Wooden, stone or concrete stoppings are built between rooms, in the lower cross-cuts and in those between levels and deeps.

The Dixon fan drives air down an air shaft 10 feet in diameter and an 8 foot pipe shaft. The air splits at the bottom to ventilate the east and west sides of the mine.

The east deep air course crosses underneath the haulage, and meets the east back deep which is the air course to No. 6 east level. At this point it crosses the haulage by an overcast and is carried down to No. 9 west level with overcasts at No. 7 and No. 8 levels. The air splits to ventilate east and west sides of the deep; the return is to the submarine headway and air shaft and to the pit bottom.

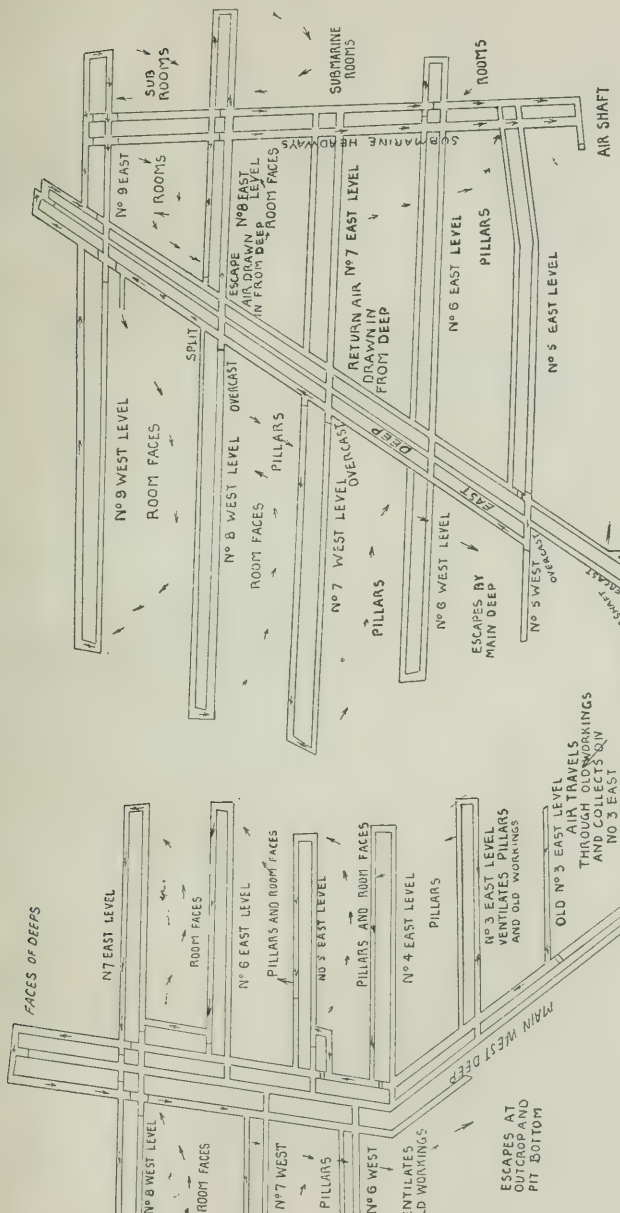
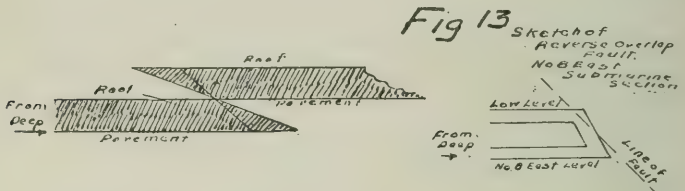


Fig 12.
SHOWING SKETCH OF MINE WITH AIR COURSES

Concrete dams were built in the outside headways of No. 8 west, west deep, and a five plunger pump, capacity 600 gallons, 150 H. P. Westinghouse motor, has been installed in a large brick pump house. This pump is proving very efficient. A twelve stage turbine pump, capacity 600 gallons, will also be installed in this pump house, but the utilization of one pump at a time will be sufficient.



Air for the west deep travels from the pit bottom through old workings and emerges on the east back deep; it then passes down this deep, around levels and up the west back deep, to the pit bottom. Some air escapes at the outcrop.

During the spring and summer of 1908 the air shaft already mentioned, the dimensions of which are 10 x 15 feet, was sunk at the top of the submarine headway.

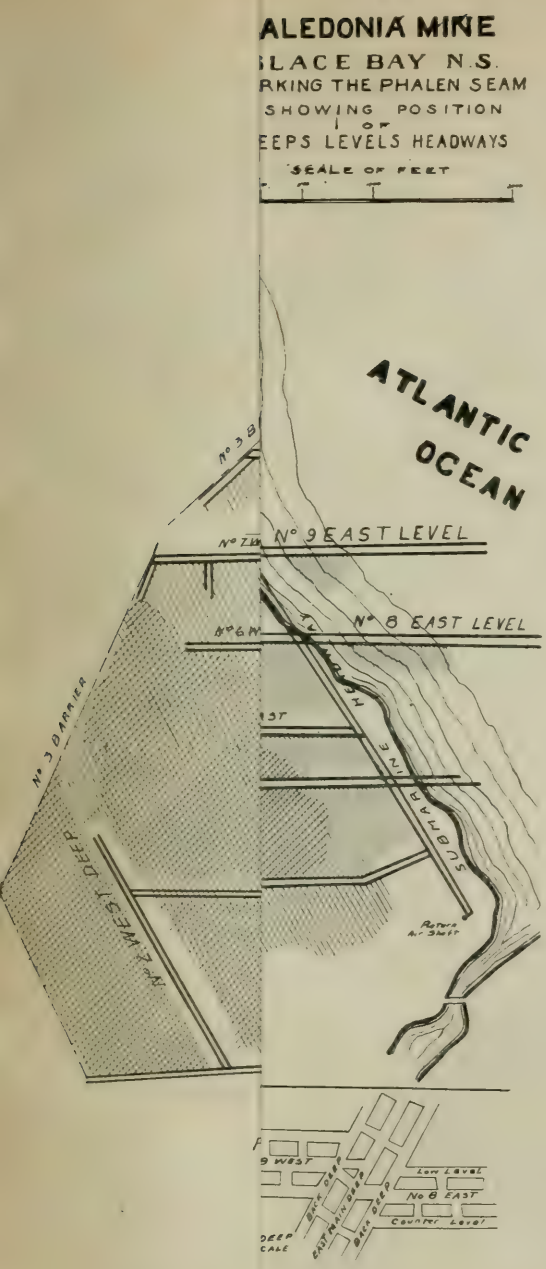
Previous to this the ventilation had been very poor on account of the long return to the pit bottom, and by reason moreover of the fact that the air is much more confined than in the west deep. The shaft will be fitted with ladders—an important consideration, since there is no slope as in the west deep. The change caused 12,000 cubic feet per minute increase for the east deep and 4,000 cubic feet decrease in the west deep, thus giving 60,000 cubic feet to the east and 58,000 cubic feet to the west deep.

Fig. 12 is a sketch of the mine illustrating overcasts, double doors, etc., and the air courses in detail indicated by arrows.

The bankhead is a large sheet-iron building of four storeys. The picking and screening plant are on the west side of the shaft.

The boiler house contains six Babcock and Wilcox boilers; the fire coal is trammed from the first floor of the bank on an overhead track.

The compressor and engine house is a concrete building containing a Matheson double cylinder hoisting engine for the man


ALEDONIA MINE
LACE BAY N.S.
RKING THE PHALEN SEAM
SHOWING POSITION
OF
EEPS LEVELS HEADWAYS
SCALE OF FEET
ATLANTIC
OCEAN
No 9 EAST LEVEL
No 8 EAST LEVEL
No 3 BARRIER
SUBMARINE
No 2 WEST DEEP
No 9 WEST
No 8 EAST
COUNTRY LEVEL

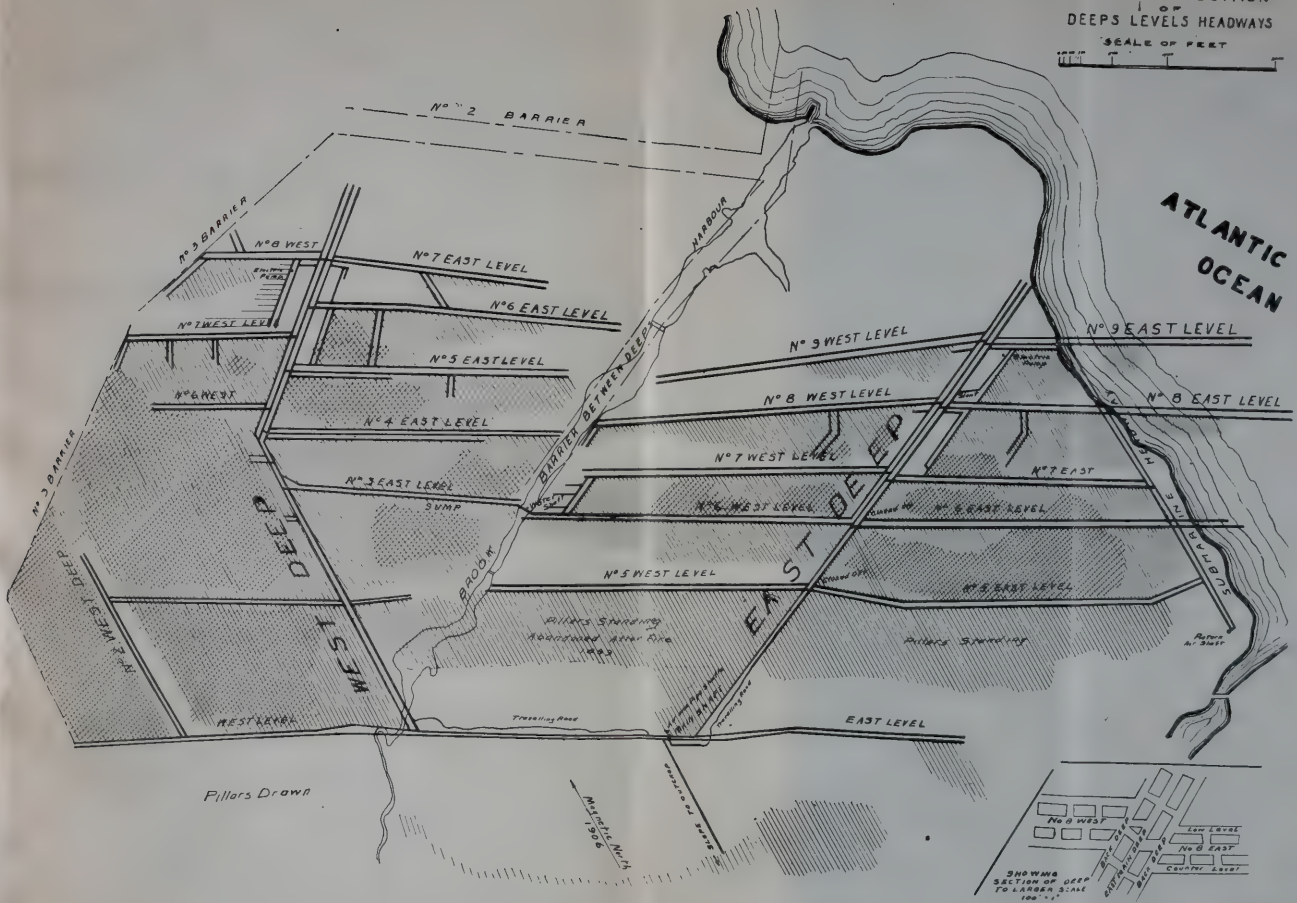
CALEDONIA MINE

GLACE BAY N.S.

WORKING THE PHALEN SEAM

SHOWING POSITION OF DEEPS LEVELS HEADWAYS

SCALE OF FEET



cage, a 15 H.P. engine for the picking belts and screens, an English double cylinder coal hoist of about 250 H.P.; an American and a Canadian Rand Drill compressor of 3,000 cubic feet per minute capacity under 110 lbs. steam pressure, also a 500 cubic foot compressor and an Atlas engine which drives the fans.

Between the boiler and engine houses is placed a 6 x 12 ft. Murphy fan, of 140 revolutions per minute, and a capacity of 85,000 cubic feet; and a 6 x 14 ft. Dixon fan, of 145 revolutions and 110,000 cubic feet capacity. The pressure is about 2 inch. water gauge. Of these fans the Dixon is in regular use.

The haulage house is situated on one side of the bankhead. It contains a single cylinder 22 in. x 42 in. engine and bull wheels for the three haulage ropes.

Over one of the tracks in the yard, empties are hauled to the high side of the bankhead. There are also five tracks for full cars, as well as tracks leading to the warehouse, etc. The position of the bankhead accounts for the curve in the yard, which curve necessitates the employment of a donkey engine to start the cars.

The plan of the mine and sketch (Fig. 4) of the surface arrangement show the position of buildings and yard.

The lack of provision for turning the west deep and level empties on leaving the cage, affords occasion for criticism. If this were provided time and trouble on the landings would be saved and the danger, which occasionally eventuates, of boxes running away down the deep when blocked out on Nos. 4, 6 and 7 east landings, would be avoided. Again it has been noted that the haulage ropes are at times started when no batteries are attached, and which in several instances resulted in a breakage with no means of stopping the rope when the accident happened. This, of course, is attributable to sheer carelessness on the part of the road bosses.

The company employ at this colliery nearly 800 men and boys, most of whom are of Highland Scotch extraction. A number of Poles, however, are employed for loading. The managers are, in every case, certificated men, while the overmen have all passed examinations for underground managers.

The writer worked in this mine for a term of nearly four months, and was occupied in bratticing, timbering, landing tending, etc.

THE INTERNATIONAL COAL & COKE CO'S COLLIERY* AT COLEMAN, ALTA.

By G. L. BURLAND, McGill University, Montreal.

Coleman, a typical mining camp of about twelve hundred inhabitants, is situated on the Crow's Nest branch of the C.P.R., in N.E. quarter of section 8, township 8, range 4, west of the fifth meridian. This subdivision is the property of the International Coal and Coke Company, who, in dividing it for sale, reserved the exclusive and unlimited right to control the liquor trade, and to divert the waters in the creeks for mining purposes. The Company supply, own, maintain and repair the water mains, drains, lighting and other town utilities. The townsite was established in 1904, and mining operations were commenced during the same year.

The coal measures are of Cretaceous age, being capped with a band of middle Cretaceous sandstones and conglomerates; and a band of Fernie shales underlying the coal measures forms the bed rock. The coal measures are distinctly defined, on the surface, by a high escarpment of conglomerate.

The strike of the bituminous coal seams is S. 11° 32′ E., and they have an easterly pitch of from 26° to 35°.

Speaking generally, the geological structure is very complex, as is shown by a sketch of a section taken by the writer along the C.P.R. track from Crow's Nest lake to Frank, where a great deal of folding and faulting is in evidence. About a mile east of the "Old Man Cave," is found the contact of the Devovian limestones and upper Cretaceous limestones and shales. About 2.5 miles east, on the contact, the strata become almost horizontal at the new

* Entered for 1909 Competition, and awarded Third Prize

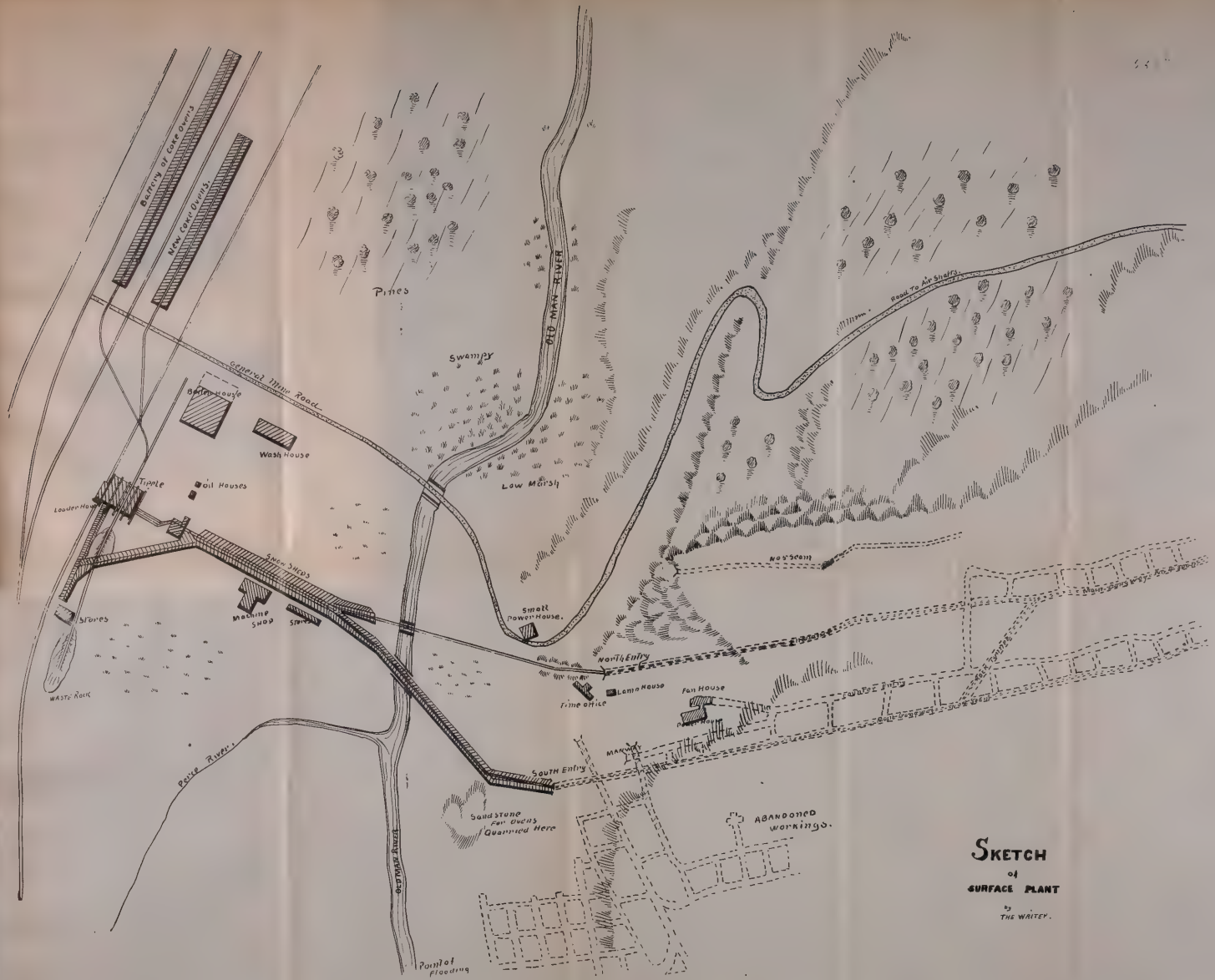

Battery of Coke Ovens
New Coke Ovens
Pines
Swampy
Old Main River
Road to Air Shafts
Tramroad Main Road
Boiler House
Wash House
Tipple
Coal Houses
Loader House
Low Marsh
Saw Shops
Stores
Machine Shop
Smith Shop
Small Power House.
New Seam
Main Gateway
North Entry
Lamp House
Fan House
Time Office
Manway
South Entry
Pound River
Sandstone For Ovens Quarried Here
Abandoned Workings.
Point of Flooding
Sketch
of
Surface Plant
by
The Waiter.

Fig. III.

An Exposure of Conglomerate.

Point of Cave "Old Mine."

townsite of Sentinel. One mile further east the track cuts through a volcanic range of hills of agglomerate ash beds. These extend to the western end of Coleman townsite, where they form a contact with a band of middle Cretaceous limestones and conglomerates, which overlie the coal measures. About this point an extensive down-throw fault causes this series to be repeated between Coleman and Blairmore.

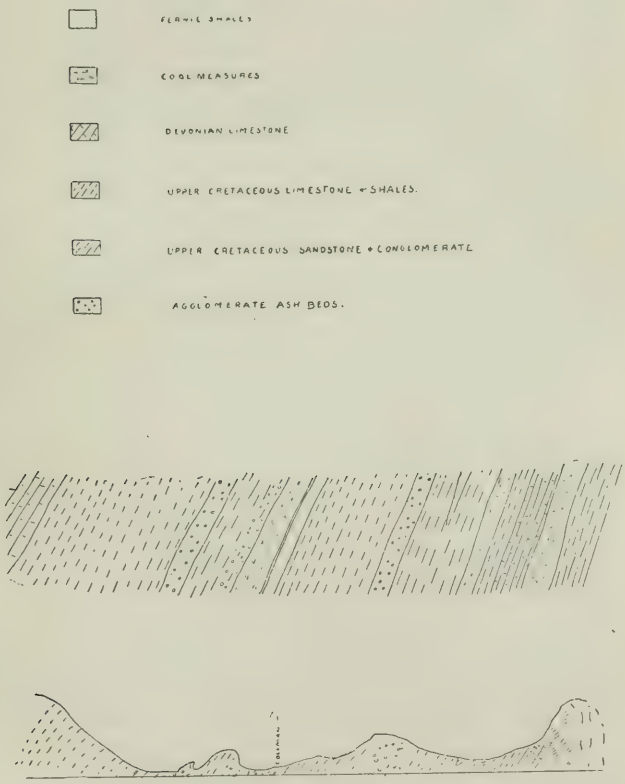


FIG. I.—Geological Section.

In all there are six coal seams on the property, of which the following particulars are available:—

No.	Av. Measure	Character.	Strike.	Dip.
1	.....	Shaly no commercial value.	S 11° 32′ E	26 °to 35°
2	16.25′	Bituminous C. C.	S 11° 32′ E	26° to 35°
3	3″ to 1′	Bituminous No C. V.	S 11° 32′ E	26° to 35°
4	4′ to 6.25′	High Bituminous S. C.	S 11° 32′ E	26° to 35°
5	6″ to 2′	Shaly No C. V.	S 11° 32′ E	26° to 35°
6	.....	.....	S 11° 32′ E	26° to 35°

These coals may best be compared with other western coals by the use of D. B. Dowling's split volatile formula, viz.:

$$\frac{\text{Fixed carbon plus } \frac{1}{2} \text{ volatile combustible}}{\text{Moisture} \quad \times \frac{1}{2} \text{ volatile combustible}}$$

Another analysis of Coleman coal was given the writer by Mr. Dickson, and shows:

No. 2 Seam.		No. 4 Seam.	
Fixed Carbon . . .	60.50%	Fixed Carbon. .	65.00%
Vol. Hyd.	25.50%	Vol. Hyd.	20.50%
Ash.	13.50%	Ash	13.50%
Moisture.	.50%	Moisture	1.00%

ORIGINAL DEVELOPMENT—OPENING WORK.

Two water level entries were driven along No. 2 seam, one sixty feet above the other, and now serve as the main and counter gangways of that seam. At a distance of 100 feet from the mouth of this drift a slope was sunk 600 feet along the coal seam, or to a depth of 279 feet below the entry. If a seam is gaseous, airways are driven parallel to the slope, one upon each side, leaving pillars of from 25 feet to 30 feet between slope and each airway. In this case, as there was little gas, only one airway was driven for the return, at a distance of 70 feet from the slope.

Work in this slope was carried on by means of a main airway and return airway for a distance of 1,000 feet to N.W. and 700 feet to S.E., the room and pillar system being employed. The workings were ultimately abandoned owing to a cave in the roof permitting the waters of the Old Man river to flood the lower levels.

As a large part of the coal occurs in the mountain above the level of the valley, the mine has been developed by tunnels entering in the outcrop at the base of the hill and running in on a grade which will just give drainage.

FIG. II.

The original or tunnel entries were driven along the coal seam with a grade of ½ to 1%. The main entry was driven for 450 feet, and was then connected to another higher passage driven

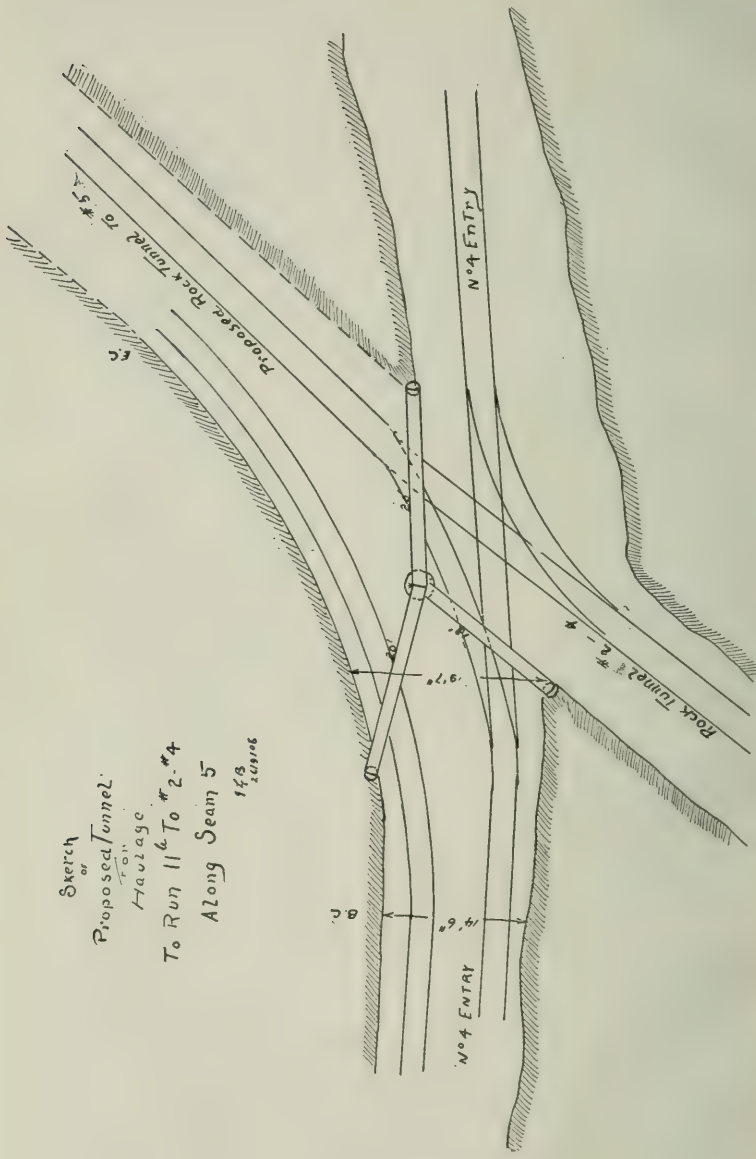


FIG. IV.—Rock Tunnel connecting Nos. 2 and 4 Seams.

from the surface. This tunnel was designed to serve as the air passage from the fan to the workings. The cost of driving the main entry was as follows:—

Coal mining and loading	$1.75 per yard.
Timber Sets	$2.00 each.
Brushing	5c. yard to 12', then 10c.
Lagging	$1.00 per yard.
Brattice Cloth	5c. per foot.
Cross-cuts	$1.00 per yard.
Chute	30c. per yard.
Posts	5c. per foot.

The tunnel from the fan on the surface to No. 2 seam is 40 feet long. The counter entry of No. 2 seam, being connected to this air flume, receives a small split of air, and is used as a man-way. Steps are built from this man-way to the main gang-way, all the ingoing shifts entering to a point some 400 feet from the south entry.

At a distance of 855 feet from the south entry, a graded rock tunnel was driven, forming an angle of 40° with the main entry, to connect with No. 4 seam, which had a dip and strike parallel to No. 2 seam. The coal seams are approximately 40 feet apart, and as No. 2 was the capping seam, the entry of No. 4 would not fall perpendicularly under the barrier protecting the entry of the upper and larger seam. No. 4 entry required to be driven at a higher elevation to give the above mentioned protection from a crush. In driving this rock tunnel, a length of 240 feet was necessary to minimize the grade due to the conditions just discussed. This tunnel connected with an entry driven from the surface along seam No. 4. Work was continued along No. 4 seam, using No. 2 entry from the rock tunnel outward for haulage and ventilation. Until June 25th, 1908, the north entry of seam No. 4 was used for haulage, and the first trip passed over a 45 lb. rail.

The size of these entries, where single tracked, is 10 feet wide by 10 feet high on the upper side, and 7 feet on the low side. Where double tracked, which is only at stations in No. 2 seam, they are 16 feet wide and 12 to 14 feet high on the upper side.

At present a 1.7 ton mine car is used. The grade for the entries may be calculated as follows:—

Let a′=Inclination
W=Weight of car=1,300 lbs.
Wc=Weight of coal=3,400 lbs.
a=Coeff. of friction=.01667

$$\text{Then } a' = \frac{a\ Wc}{2W + Wc} = \frac{.01667 \times 3400}{2 \times 1300 + 3400}$$

$$= .009$$

Or a grade of nine-tenths of one per cent.

The Company intends to increase the capacity of the mine cars to two tons, which would then necessitate a grade of 1% to make the pull both ways approximately the same. At the start of operations a grade of five-tenths of 1% was provided for, but as work progressed this was gradually increased, until finally a 1% grade will be maintained.

A ditch on the same grade, 3 feet wide by 1.3 feet deep, was dug on the slope side of either gangway to carry off water in the mine.

METHOD OF WORKING.

The mine is worked upon the panel system, that is, the workings in the seam are divided by barrier pillars into a series of mines, which are only connected by the counter entries. These barriers are 550 feet apart and are 110 feet thick. Between the barriers narrow rooms or stalls are driven up the coal seams from the counter entries in each seam, to the limit of the coal. Wide pillars are left on either side until they reach the limit of the seam; then the pillars are drawn, as the miners work down the room again to within three cross-cuts of the counter entry. This panel system is economical, as it affords separate ventilation for each panel. Explosions in one panel would not necessarily affect the adjoining panel. Also, the air flow can be regulated according to the amount of gas in the workings.

The main entry of No. 2 seam has now been driven a distance of 7,500 feet in from the south entry (i.e., the entrance to No. 2 seam is the south entry, while entrance to No. 4 is the north entry). The counter entry runs parallel to it at a distance of 60 feet up the pitch of the seam. The gangway of No. 4 seam is 5,440 feet, and runs parallel to No. 2 seam, its counter entry

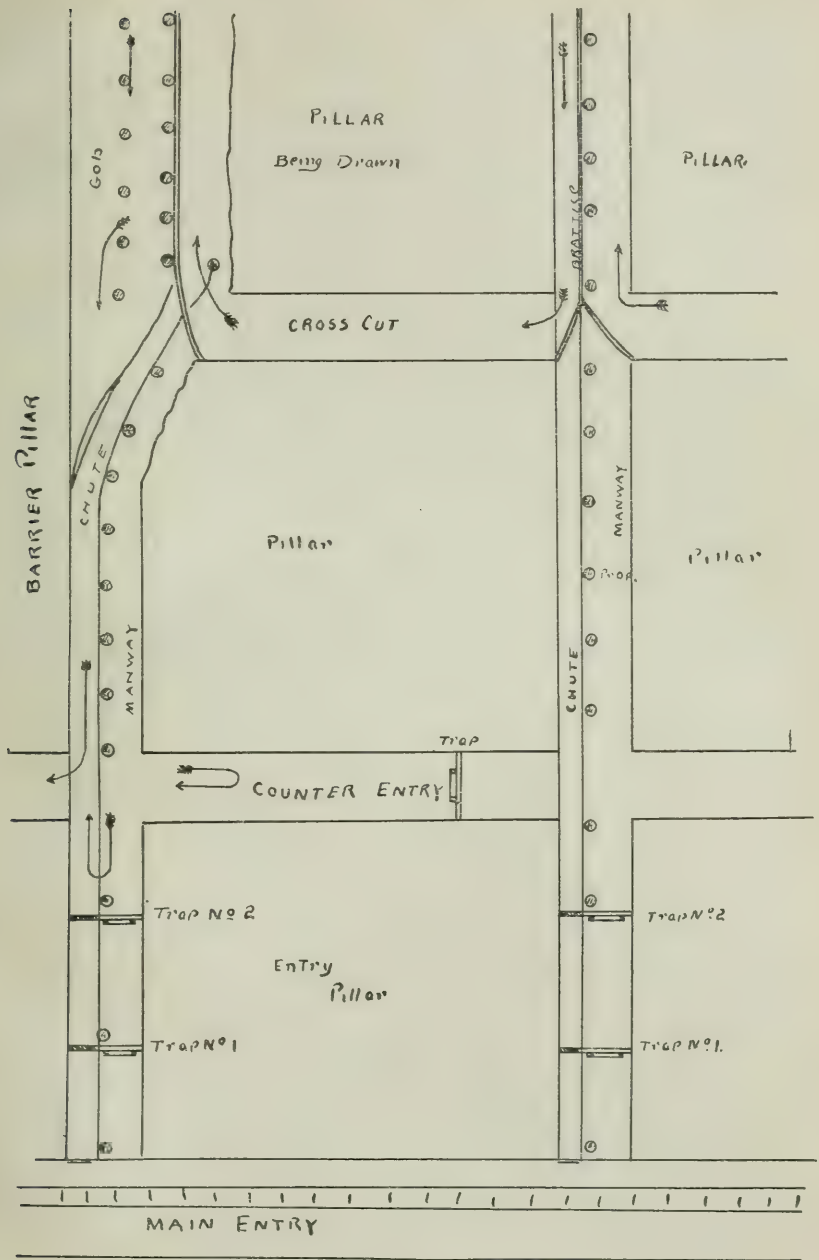


FIG. V.—Sketch showing Panel System.

occupying the same relative position. At points 60 feet along entries, at right angles to them, cross-cuts are driven up the pitch to the counter, those in No. 2 seam being 8 feet wide x 6 feet high; in No. 4 seam, 8 feet wide by the thickness of the coal. These cross-cuts are driven up from the counter entry, except where they would cut a barrier pillar, when, as before explained, they are 10 feet wide by the depth of the seams, and are called rooms.

The conditions influencing the extraction of coal are:

(1) Weight of overlying strata. There is, for example, a great pressure on the pillars in No. 4 seam, and on account of the narrow bed of rock separating the two main seams, it is necessary to provide that the pillars and barrier pillars of No. 2 seam shall be directly over those of No. 4.

(2) The strength of the roof. In No. 2 seam there is very little danger of caving, although a creep on a small scale might occur if the pillars were at all off line with those of No. 4 seam. If, on the other hand, the pillars were decidedly off true, so that a pillar of No. 2 seam was over a gob or room of No. 4, a series of caves and creeps would occur. In No. 4 seam a great deal of trouble is caused by caves, but little from creeps. There being a very solid floor to No. 4, very few, if any, creeps are noticed. The pressure of No. 2 seam on No. 4 workings will be calculated later, when dealing with timbering.

(3) The floor is sandstone overlaid with shales and fire clay. No sills, practically, are required to carry the ties, as few creeps take place, and those unimportant as a result of the care taken, as above explained, in surveying the mine. This hard floor is a good feature in the International Company's mine, for it allows a smaller pillar to be used than would be necessary if the floor were soft. Narrow pillars yield on soft floors, producing caves and creeps.

(4) The texture of the coal being soft, all work such as cutting, boring, etc., is done by hand. The grade of the seams, or more properly, the dip, being 30° approximately, is just sufficient to allow the coal to pass freely down the chutes.

To calculate the width of the pillars, the following approximate formula may be used.

Let x = width of pillar
y = average depth of coal seam
z = average thickness of coal seam

$$x = V\,y \times z$$

$AB = CB \cos 60° = \cos 60° = 382'$

$$\text{Average thickness of rock above coal} = \frac{AB + CO}{2}$$

$$= \frac{10 + 382}{2} = 196'$$

Average thickness of coal seam = 16′

$$\therefore\ x = V\,196 \times 16 = 56'$$

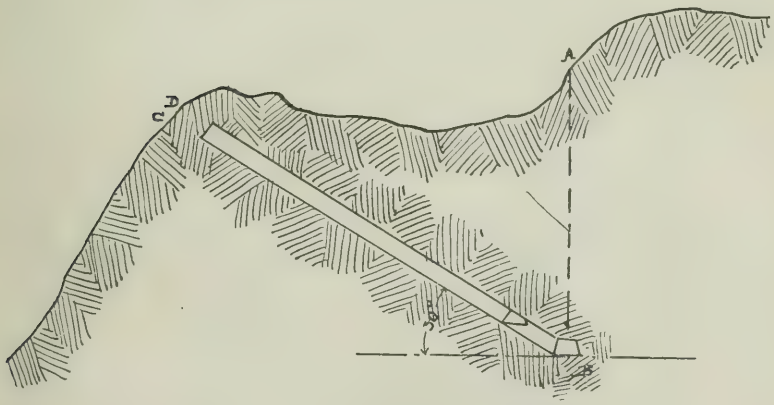
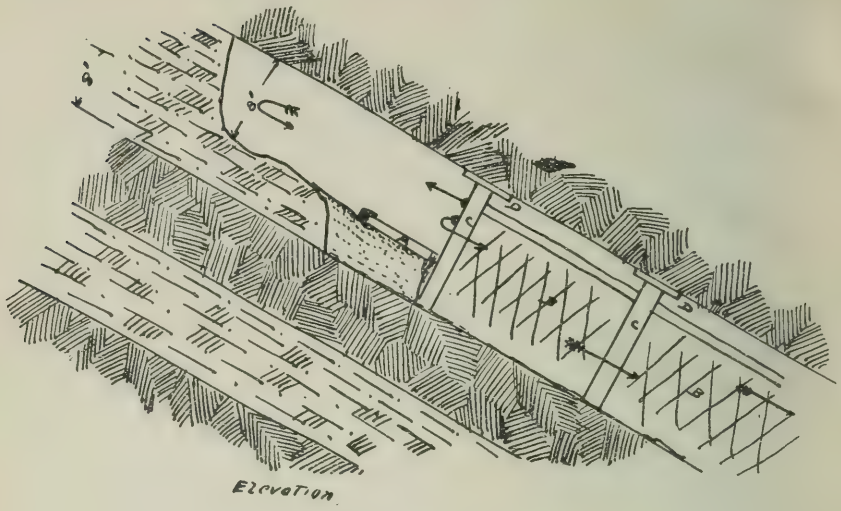


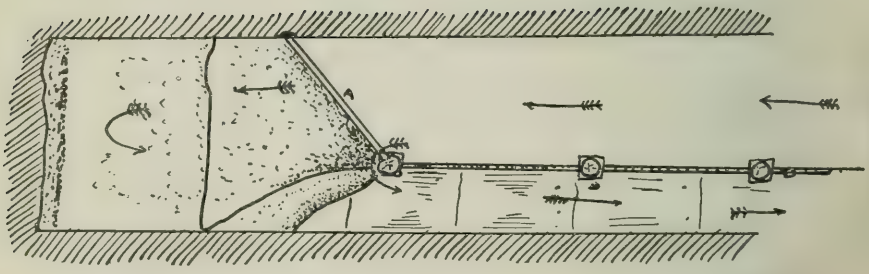
FIG. VI.—Cross Section of a Room.

The pillars would be approximately 56 feet wide. They are actually 50 feet wide.

Along one side of each room a manway is built, and on the other side a chute, which is 3.5 feet wide by 3 feet to 5 feet high, the bottom being of sheet iron. Through these chutes the coal passes by gravity to the main entry, where it is loaded by the chute buckers into mine cars.

In each panel there are ten such rooms driven parallel to each other. All cutting and holing is done in the mining bench.





Plan + Elevation
Showing
Working Bench
&
Air at Face.

FIG. VII.

This is mined back by hand, with an occasional shot or two, for 12 feet by 8 feet depth in seam No. 2. The coal is finally liberated by firing two shot holes 18 feet from each rib to a depth of from 6 feet to 7 feet.

The working of No. 4 seam is identical with that of No. 2, except that since the structure of the coal is soft, it is not required to use powder. The pillars of No. 2 and No. 4 seams overlie, there being only 4 to 5 feet of rock between the two seams which is not sufficient to prevent a crush.

When robbing pillars the work must be kept in line to prevent any undue pressure falling on an individual prop. The pillars should not be robbed too near the entry pillars, and in the mine 200 feet is left above the main entry. Work is commenced 50 feet from the glacial drift near surface, and by means of stripping a skip of from 10 to 15 inches from the rib, the pillar is drawn. Barriers are built to protect the underworkings from a surface crush. The accompanying sketch will illustrate the method employed.

FAULTS.

Upon arriving at cross cut 120, leading to room 120, a fault was encountered. This fault cuts the strike of No. 2 seam at right angles, running S. 78° W. Its effect upon No. 4 seam has not been ascertained, for that entry has only been driven in as far as cross-cut 85. On the main entry the dip of the fault is from vertical to 85° towards the north. In spite of the fact that the cap rock of the entry is of shales underlying the conglomerate, the face of the fault is the conglomerate itself, the shales having disappeared. The counter entry has been driven to meet the fault, and the coal traced to left for fifty feet. Below, on the main entry, the coal has the appearance of having been pinched out. This last fact has been disproved after locating and tracing the surface outcrops for a considerable further distance.

No disturbance as yet has been found upon the surface to indicate the exact location and nature of the fault; but its location has been theoretically determined by means of the mine maps. At a distance of a few hundred yards past this point, the strike of the conglomerate noticeably changes to a direction of about twenty degrees to the west.

The output will not be restricted during the driving of a rock tunnel through the fault, since development has been maintained well in advance (see footnote).

CALCULATION OF TONNAGE ALREADY DEVELOPED.

Sp. G. of Coleman Coal (approx. average).
Approx. W = weight in air of piece of coal = 266 oz.
w = weight in water of piece of coal = 66 oz.

$$\text{Sp. G.} = \frac{266}{266-66} - 1.33$$

$$\text{Now weight of 1 cu. yd. of Coleman} \frac{\text{steam + coke coal}}{2}$$

$$\text{or average cu. yd. of Coleman coal} \frac{62.5 \times 27 \times 1.33}{2000} = 1.22 + \text{short tons.}$$

By finding total number of tons in seam up to the fault, then deducting number of tons already drawn, we can get a fair figure as to the standing of the company should the fault cause considerable delay in development.

1ST NO. 2 SEAM.

TOTAL CAPACITY OF SEAM.		PROTECTION PILLAR LEFT FOR ENTRY.
Total length of entry.....	7740 ft.	7740 ft.
Average pitch length.....	764 ft.	200 ft.
Average thickness.....	14.5 ft.	14.5 ft.

$$\text{Total no. of tons} = \frac{7740}{27} \times 764 \times 14.5 \times 1.22 = \frac{7740}{27} \times 200 \times 14.5 \times 1.22$$

$$= 3783064.32 - 108592.2$$
$$= 3674472.12 \text{ short tons.}$$

Average handling capacity from opening of mine
= 1400 tons a day (from No. 2 seam)
1400 × 300 × 4 or 1,680,000 tons have been drawn, leaving 1494472.12 tons above the main entry.

The present average capacity is 1700 T. a day, consequently sufficient coal has been developed to provide for 879 days or 2.9 years continuous mining.
No. 4 seam must be worked at the same time, up to the fault.

TOTAL CAPACITY OF SEAM.		PROTECTION PILLAR LEFT FOR ENTRY.
Total length of entry.....	7740 ft.	7740 ft.
Average pitch length.....	700 ft.	200 ft.
Average thickness.....	6 ft.	6 ft.

$$\text{Total no. of tons} \frac{7746}{27} \times 700 \times 6 \times 1.22 - \frac{7740}{27} \times 200 \times 6 \times 1.22$$

$$= 1050529.80 - 420211.92$$
$$= 1050529 \text{ Tons.}$$

MINE TIMBERING.

The roof is, generally speaking, firm. For timbering in the rooms the following scale to determine the size of props is found to answer, namely, diameter in inches = length in feet.*

In actual practice the props used by the International Coal and Coke Co. in seam No. 2 are 8 inches in diameter and are spaced 8 feet apart. Similar timbering is in use in the rooms of seam No. 4.

The Timbering of the Face of Workings. — Props, when placed in position, are at times subjected to excessive strains, which necessitates care in setting. Fig. 1 shows the result of careless work; the post splitting at A and B. Fig. 2 represents the manner in which the props are set, namely, perpendicular to the roof and floor wherever possible, thus counteracting the effects of pressure and sliding. (Refer to fig. 3.)

In the International mine the posts slant up the pitch about eight degrees. It is also underset, to overcome any sliding which may occur in the roof. A rule occasionally followed is that the

---

*To find load prop will support, consider the average crushing strength to be 8,000 lbs. per square in. The timber used is fire-hardened rampikes of pine.

Average formula = area in sq. in. $\times$ $\frac{1}{2}$ average crushing strength

$$= 3.1416 \times \frac{(16)^2}{(2)} \times \frac{8000}{2} \times \frac{1}{2000}$$

= 95.7 tons, or nearly 95 T. approx.

As the roof is good, the weight may be regarded as $\frac{1}{2}$ width of room upon them.

Hence: weight of roof cu. ft. $\times$ $\frac{1}{2}$ width.

$$= \frac{10}{2} \times 160 = 800 \text{ lbs. or say } \cdot 5 \text{ T.}$$

Each prop can support 95 T., $\therefore$ 1 prop can support $\frac{95}{.5}$ sq. ft. of roof.

1 Post every 19′ would be sufficient.

Based upon this theoretical calculation, a prop $\frac{1}{2}$ diam. at $\frac{1}{2}$ distance would serve as well.

No. 4 seam has been worked 3 years at an average of 500 tons a day.

Output = 500 $\times$ 300 $\times$ 3 = 450000 Tons.

There remains 600,529 tons.

Present capacity = 700 T. per day, or sufficient to supply the coke ovens 856 days, or 2.85 years.

Or both these sections of the seams would give an output for approx. 2.9 years.

The writer has not taken into account all the coal down the dip of the seams from the gangways.

post should be 1.015 multiplied by the perpendicular distance between the roof and floor, less the thickness of the cap and cushion. Thus, assuming the average perpendicular distance to be 14 feet, the length of prop = (14′ 6″ ″pad and cushion) × 1.015 = 164.4″ or 2.5 inches greater.

The post is cut to the correct length. The cushion, if one is required, is prepared, and the post is forced into position with the crown piece in place. Wedges are then driven in to secure the prop during blasting operations. The props also serve as supports for the brattice cloth used in ventilation.

At the face, where the pressure is continually changing, in consequence of drawing the pillars, great care must be exercised in placing the props so that they will receive an equal strain. Also in case of a crush, the weight must be distributed equally upon the props. Again, the props should be kept in regular rows, spacing them regularly, none having more roof than the next to support.

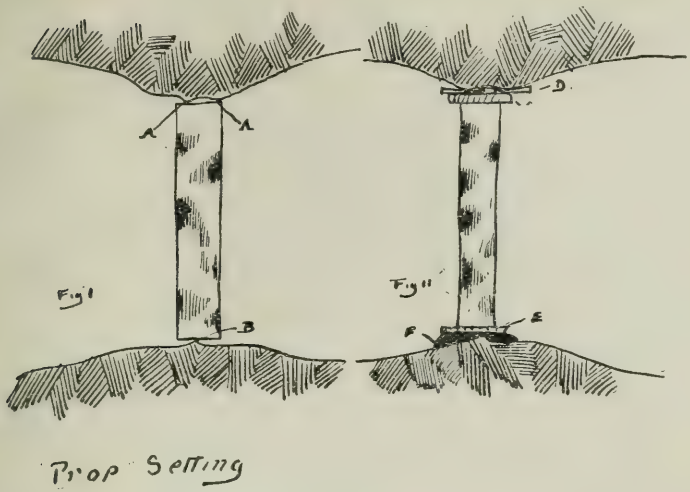
Referring further to the timbering of the main entries, the method employed is, to place two posts and a cap piece with a joggle cut about 1.5 inches to give greater sliding resistance. In No. 4 entry a great pressure falls upon the sets. It may be of interest, therefore, to calculate the relation between the round timber and square sets.

Let W = load (breaking)
f = crushing load (Pitch Pine) = 5,000 lbs. per sq. in.
I = moment of inertia
l = length of beam in inches = 12′ x 12 = 144″
d = depth of beam in inches = 12″

$$\text{Or } W = \frac{16fI}{ld}$$

Assuming the caps (round) to be 12″ diam. and square set cap. 12″ x 9″, the moment of inertia of square piece $= \frac{bd^3}{12} =$

$\frac{9 \times (12)^3}{\quad} - 1296$, then $W = \frac{16 \times 5000 \times 1296}{12 \times 12 \times 12 \times 2000} = 30$ T.



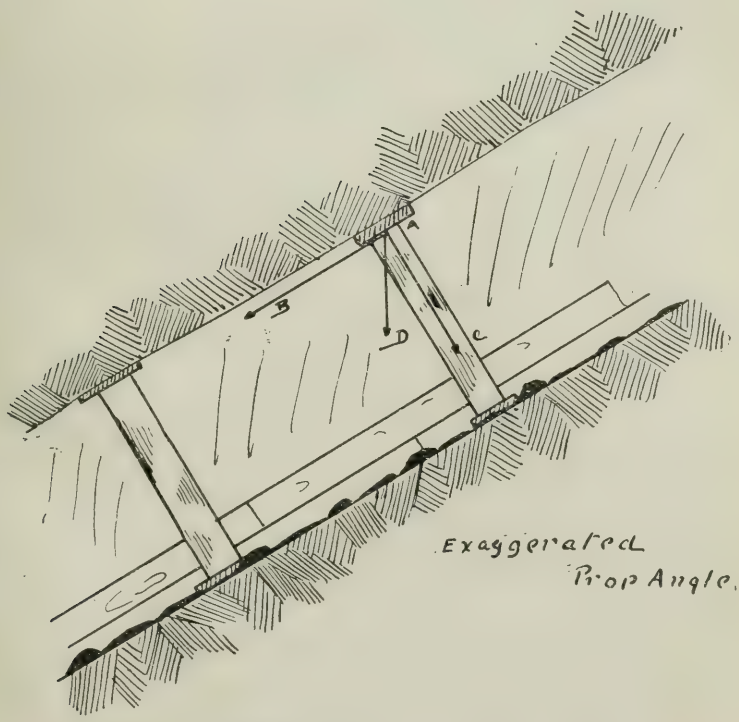


FIG. VII.—Sketches illustrating Timbering Methods.

For round sets the strength of the beam, or cap, is proportional to d^3 where d = diameter,

$\frac{}{l}$ l = length

For square sets the strength of the beam, or cap, is proportional to bd^2 b = breadth

$\frac{}{l}$ d = depth

l = length

Calling strength of square set (A) 30 T., then

$$\frac{X}{A} = \frac{d^3}{1/} \qquad \frac{/bd^3}{3} = \frac{dè}{bd^2} = \frac{(12)^3}{9(12)^2} = \frac{4}{3}$$

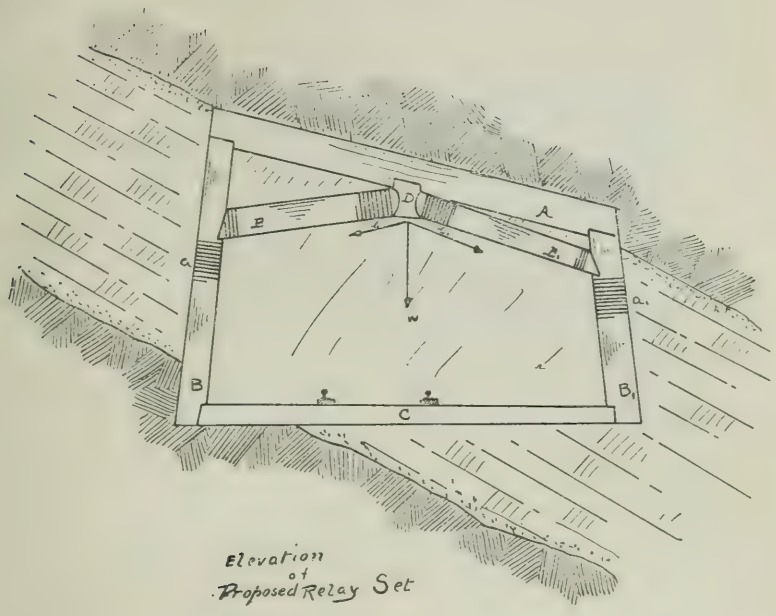
$$\text{then } \frac{X}{30} = \frac{4}{3} \text{ or } X = 40 \text{ tons.}$$

Now the working load is one-third breaking load; therefore the working load of round sets = 13.3 tons; and that of square sets = 10.0 tons.

Thus it will be noted that the engineers have selected the strongest class of props for their sets in proportion to size of timber used. Some other scheme to rectify the breakage continually occurring in No. 4 entry, which is likely to cause a serious accident to the haulage system, may therefore be considered.

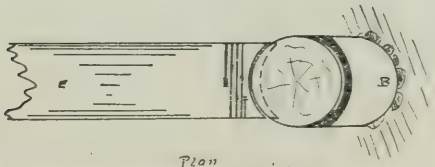
The writer has designed an original set of timbering for use at points where the strain is greatest. The object being to economize space, since provision must be made for the passage of the air locomotives; to provide a set of timbers possessing double the strength of a single cap; having a certain elasticity to withstand shocks, and, as the strain increases, that each portion shall act back upon any weakened link, counterbalancing any over proportional strain; having no joggles whatever to weaken the posts.

By providing a well braced cap, this set should prove satisfactory as a relay in a series of heavy single sets. In the parts where the strain is heaviest, it is suggested that there be one relay to two single props. The relay would receive any shock, the strain coming upon the two supporting sets after the destructive jar had been broken. The relay should be so placed to receive the shock just in advance of the sets on either side, and yet not be required to sustain it more than momentarily.



Elevation of Proposed Relay Set

-: Plan :-
Showing Proposed Method of Fitting and Binding Wedge Beams E E1 at "D"



Plan
Showing proposed Method of Fitting and Binding Wedge Beams E E1 at "B B"

FIG. VIII.—Sketch of Proposed Relay Set.

Referring to the sketch, it may be explained that a set of 14″ diam. posts, having a 12″ lap, and joggles similar to the general sets, is built to scale. A sill is laid and anchored between —and not as usual, under— the posts B & B′. The wedge beams E & E′ fit into joggles in posts B & B′. Below the joggles the posts are reinforced by windings of stout iron wire. The upper end of the wedge beams are grooved to fit snugly on a hardwood block " D," whose upper end is also grooved to fit against the cap piece A. E & E′ are also strongly reinforced with iron wire at b & b′. The wedge lever beams should be of the same diameter as the props used in the rooms, namely, 8 inches, and should be of fire-hardened rampikes, which are light and can stand great pressure.

The theory is that the strain W acting vertically downward, is resolved into components at D acting along E & E′, with very little shearing stress, but great compression. Being reinforced, EE′ stands this, and if the strain falls a little more on E than E′, post B will act upon C, which in turn acts upon B′ so to E′, pressing E′ upon D and maintaining the wedge pressure primarily established. As a matter of fact, the movement of the posts will be found to be very slight.

From a previous formula: The load these wedge lever caps would sustain, or, in this case the compression, = area in sq. in. $\times \frac{1}{2}$ crushing strength $= 3.1416 \times \frac{(8)^2}{2} \times \frac{8000}{2} \times \frac{1}{2000} = 99.5$ ton.

Assuming a factor of safety of 3, the safe working pressure load of this set will be $\frac{1}{3} = 33$ tons, against 10 tons supported by single set.

This device is cheap and effective. Only in places where the rock between No. 2 and 4 seams is cracked need any danger of a crush be feared. The installation of fifteen such wedge beam sets would be sufficient to afford a safe and well timbered gangway.

In No. 2 seam the roof is good, and the general timbering is only required in places where small caves are apt to occur.

MINE HAULAGE.

Animal haulage was employed in the early stages of development, but was replaced when the mining had progressed sufficiently

North Entry.

Boiler and Power House.

to render the instalment of a motor haulage plant economical. The choice was between electric power, compressed air, and rope haulage.

The use of endless rope haulage could not be favourably considered, since for this system a double track is requisite. In a pitching seam, such as No. 4, this would entail a great outlay for rock cutting, as the entry reaches its maximum in the narrow seam.

The tail rope system is more suitable for short entries; therefore with workings in a distance of 7,000 feet (and in a few years' time twice this distance will have been attained) such a system would not be efficient.

Electric haulage had the advantage of high efficiency and of not requiring as much head room in the entries as either compressed air motor or horses, and modern invention has greatly lessened the liability to fires and gas explosions from sparking, short circuits, etc. The gathering locomotive, with reel and cable, also has several very admirable features. On the other hand, it was not felt that absolute sparklessness had yet been attained, and as the mine is likely to become both dusty and gaseous as it is extended, it was decided to avoid even the slight risk still involved in the employment of electric apparatus.

The Company therefore chose air power for the main haulage, the air being supplied by a four-stage Rand compressor delivering 1,000 lbs. pressure at the gauge. An advantage here considered was that in the event of mine accidents air could always be supplied to imprisoned men by breaking an air pipe. Again in the case of fire, the line of pipes could also be used to carry water, avoiding the delay of laying special lines to conduct water to where required.

In the No. 2 mine there are four haulage stages, of which the inner gathering stage is the shortest, owing to animal power being used. This stage is from the face to cross-cut No. 108, the method employed being to sprag the empty cars at the different chutes to be bucked, on the in-trip. The horse on the return starts the inner car, and, assisted by gravity, the full cars are collected and taken to cross-cut 108. At this point, which is the beginning of stage 3, No. 3, or inner locomotive, takes this outbound trip, and, while pushing them, collects the cars as they are loaded

between 108 and 76. This air dinkey in turn delivers its train at No. 76 cross-cut to No. 2 dinkey in exchange for its empties, and pushes the trip to cross cut 30, where it in turn exchanges with the outside haulage dinkey, which pulls the load direct to the scales at the tipple.

In No. 4 seam the out-trip is drawn by horse power to the second rock tunnel connecting seams 2 and 4 (approximately at chute 46). The cars are run into the tunnel to await the arrival of the incoming trip. Upon its arrival, the dinkey hauling the empty cars turns into the rock tunnel, and its load of empty cars is taken in tow by two stout horses. The switch is again turned and the dinkey "Canonball" takes the loaded cars directly to the tipple.

MINE VENTILATION.

The Government requirements are very definite and are strictly enforced.

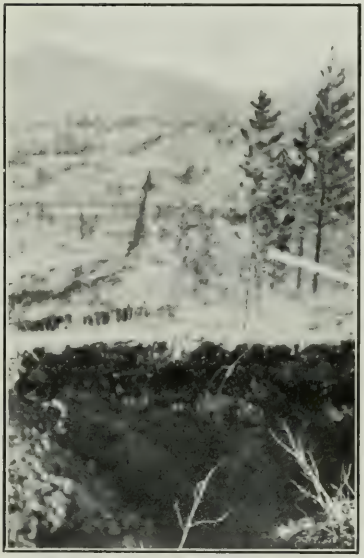
In No. 2 seam there are three splits, and in No. 4 seam one split, providing air sufficient for 320 miners.

In practice 150,000 cubic feet per minute is supplied by the at the I. C. & C. Co.

In preparing the ventilation scheme the first point to be considered was upon what principle the ventilation should be carried out, i.e., by exhaust method or forced current. The heavier gases, such as hydrogen sulphide and carbon dioxide, are more easily handled by exhaust, under the conditions of the International mine, as they tend to sink to the entries. The lighter gases, such as marsh gas and carbon dioxide, have low specific gravities and will tend to rise to the higher parts of the rooms. In the seams under discussion, the carburetted hydrogen and carbon monoxide are the chief impurities in the workings; hence the old system of exhaust was changed for forced current draft. Again, a feature not to be overlooked is the danger of dust explosions when mixed with marsh gas or with the carbon dioxide which may be generated by blasting explosives; thus the gas should be driven away from the entries.

The danger of fires from spontaneous combustion is remote in the mine, as nearly all fires originate from the oxidation of the slack left in the gobs, or from the oxidation of pyrite, the sulphur, upon being set free, having a low point of

Air Way.



Cave in Upper Workings.

ignition. Fortunately the coal carries comparatively little pyrite, and gob fires are scarcely possible, as all the slack is drawn out for utilization in the manufacture of coke.

With reference to flow sheet of air current, which the writer prepared to facilitate the study of the air flow, it will be noted that the air splits at the first rock cut. The air for No. 4 seam branches at this point and flows down the tunnel to the main intake of the seam. Tracing in part the passage in No. 2 seam will sufficiently illustrate the principle, which is also employed in No. 4, and will at the same time avoid repetition.

The three splits travel down the gangway, or intake, of No. 2 seam to cross-cut No. 125, which is approximately at the face of the main entry. Guided by brattice cloth, they turn up the cross-cut to the counter entry (the sketch more clearly illustrates this point). Again guided by brattice cloth, they sweep to the face of the counter and return upon the other side of the brattice on their way to the upper rooms. Following No. 3 split, the current then travels up and down the ten rooms in 100 panel; thence passes on to No. 99 room, passes up to the face, returns, then crosses over through cross-cut 98, up on intake (manway) side of brattice to the face, and returns down the chute side to the counter, to 96 room. It must be remembered that 97 room is not driven above the counter entry, as the pillar between No. 96 and No. 98 is utilized as a barrier. Sweeping up room 96 to the face, the air proceeds from room to room by the upper cross cuts until it reaches room 87, from which it escapes to the atmosphere.

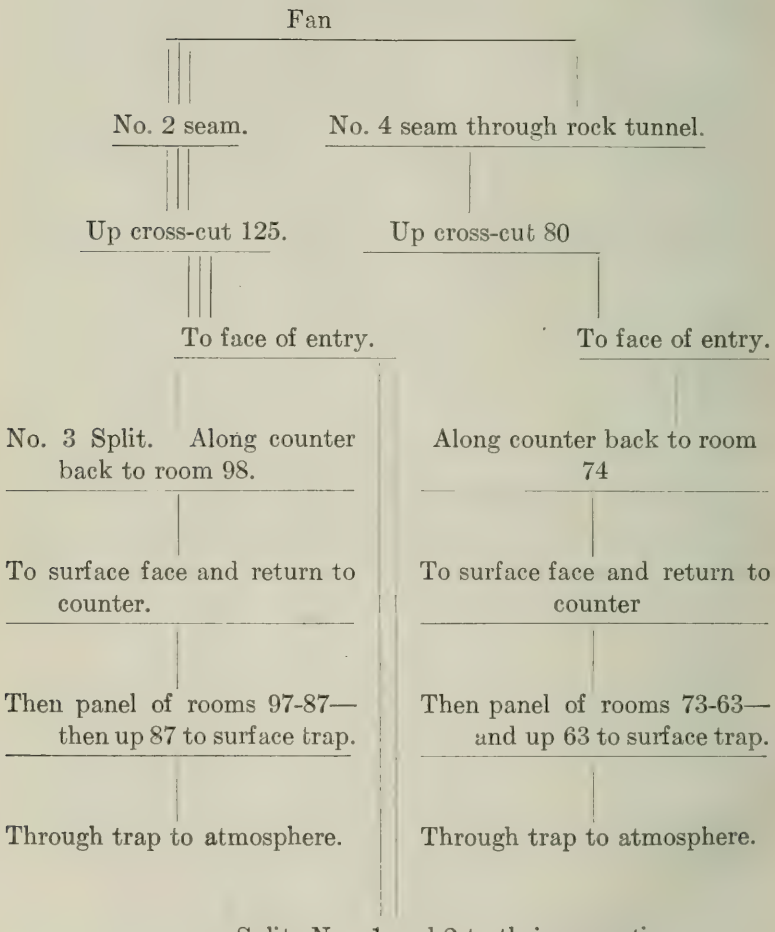
No. 1 and No. 2 splits of the large seam are handled in identically the same way as No. 3, as above described. The splitting is accomplished by means of a regulator, or a trap whose opening can be altered to vary the current. When a split is again split, as in the case of Nos. 1, 2 and 3, the terms primary, secondary and tertiary are respectively applied to them.

Future Prospects.

The total length of the seam opened by the I. C. & C. Co. is 26,400 feet, or 18,660 feet past the fault.

FLOW SHEET OF AIR CURRENT.

"Present System."


Fan
No. 2 seam.
No. 4 seam through rock tunnel.
Up cross-cut 125.
Up cross-cut 80
To face of entry.
To face of entry.
No. 3 Split. Along counter back to room 98.
Along counter back to room 74
To surface face and return to counter.
To surface face and return to counter
Then panel of rooms 97-87—then up 87 to surface trap.
Then panel of rooms 73-63—and up 63 to surface trap.
Through trap to atmosphere.
Through trap to atmosphere.
Splits Nos. 1 and 2 to their respective panels, thence to atmosphere.

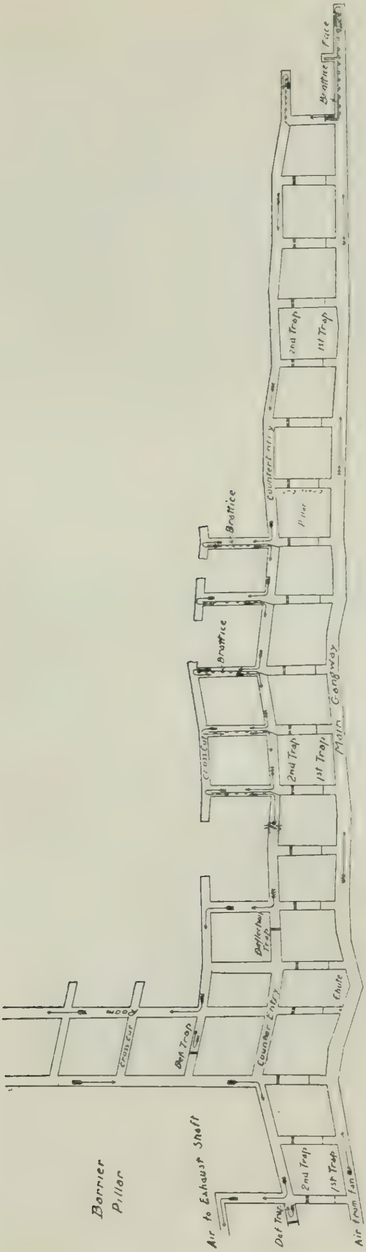


FIG. IX.—Sketch of Air Course and Brattice Cloth Regulators.

Assuming, as before, that slant pitch in No. 2 seam is 764 feet (it is, in reality, greater in places), the total amount of coal to be mined past the fault is $\frac{18660}{27} \times 764 \times 14.5 \times 1.22$

$= 9{,}408{,}458.4$ tons, or 18.45 years' supply.

The future extraction of the protecting pillars along the entries will be effected by mining another rock cut entry along No. 5 seam, the seam itself not being of sufficient width to allow of the driving of an economic coal gangway. This entry will be parallel to the original entries in 2 and 4 seams. The work has been commenced, and will be pushed forward until it is decided to rob the protecting barriers of the former haulage roads.

Robbing barrier pillar along No. 2 seam—108,592.2 tons—at an average of 600 tons a day, would take .6 years to draw.

Above the main gangways (the ratio of No. 2 seam to No. 4 seam with respect to time being 1) the available coal is sufficient to provide for 2.8 + 18.45 + .6, or 21.85 years' supply, at the present rate of output. The tonnage below the main entries

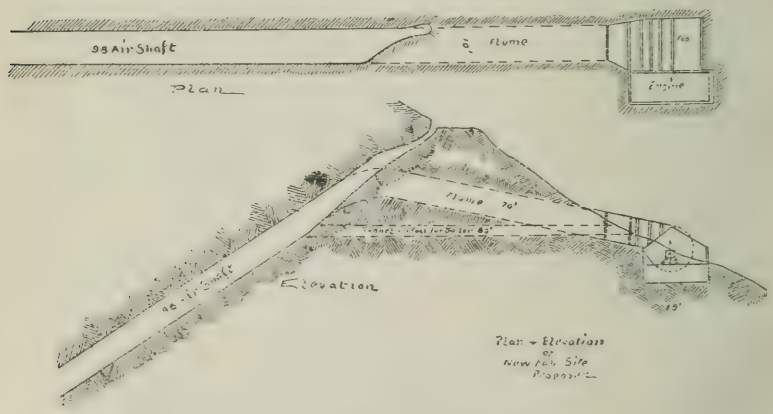


FIG. X.—Plan and Elevation of Proposed New Fan Site.

would probably extend at least 1,000 feet, and as the coal could not be mined at same rate as in the workings above, the Company can mine coal at the present rate for at least some 70 years to come.

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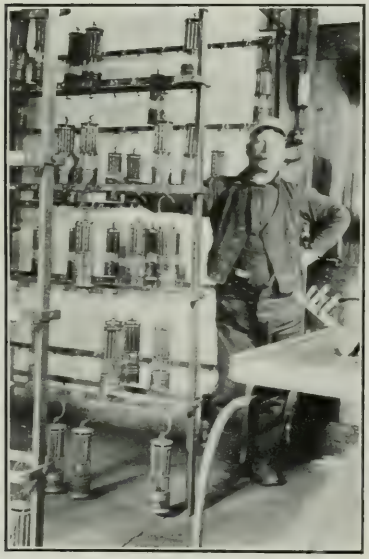
Main Office.



Lamp House.

The lower workings are also to be reopened in the near future by a slope, plans for which, however, are not as yet completed.

The Surface Plant and the Coke Ovens.

The dinkeys take the outbound trip to the scales through a long snow shed. The loaded cars are passed over the scales, and the brass check, with the number of the miner's contract, is removed, and the net weight of coal credited to him on the work sheets. From the scales the cars run by gravity to the hoisting tower of the tipple.

Hoisting is done by two automatic self-dumping skips working in balance, and is operated by a 75 H.P. 14½ inch by 20 inch double cylinder hoisting engine, made by the Jenckes Machine Co.

Upon dumping, the coal is sized over stationary screens, as illustrated by the accompanying flow sheet. (1) Over 4 inch bar screens with a pitch of 30°; oversize goes to two link-belt picking tables 5 feet wide and 40 feet long. On these tables it is hand picked—rock being sent to the waste bin, and coal to the storage bin. (2) Undersize over 2 inch screens at same pitch. Its oversize passes to the 5 foot picking tables above referred to, so that the coal proceeds along the tables in two layers, the 4 inch and over forming top layer, and oversize of 2 inch screens the under layer. (3) The undersize of the 2 inch screens goes to two additional tables, or may be deflected by a system of gates to a conveyer, which takes the fine coal to a Bradford breaker, where it is reduced to slack for the coke ovens.

The fine coal from the second set of picking tables, which does not go to the Bradford breaker, is conveyed to the "run of mine" bin, and is mixed with the larger coal. The coal is loaded into box cars by an Ottumwa box car loader. This loader will fill a 30 to 40 ton car in 5 to 7 minutes.

The undersize of the 2 inch screens can be diverted, by raising a flop-gate, to a link-belt conveyer, which carries it to a 9 foot Bradford breaker. The breaker is a revolving screen of special design, with ½ inch perforations. The coal, on entering, is carried part way around the inner circumference by projecting shelves and lugs, and as it falls, breaks by its own weight, until sized to pass

through the perforations. The rock being harder than the coal will not break, and is discharged into a rock bin. This type of breaker acts as a crusher for coal and a picker for the rock and slate.

The slack from the Bradford breaker, when two parts of "4" seam coal are mixed with one part of "2" seam coal, falls into a storage bin, from which it is conveyed by larries to the coke ovens. These larries are driven by a 35 H.P. Westinghouse motor.

The usual charge at the ovens is from 6 to 6½ short tons, the time allowed for burning being approximately three days, depending, however, upon the flame, which is an indication of the completion of the burn. When the coke is finished it is quenched to make it crack and cool quickly, the walls retaining their heat to spontaneously start the next charge. The resulting coke contains approximately 18% ash, plus a small percentage of volatile hydrocarbons. Six tons of coal produce 4·29 tons of coke, each oven producing approximately 38·5 tons per month.

THE CONSTRUCTION OF A MODERN BEEHIVE OVEN.

The writer had an opportunity to follow to the smallest details the construction of a battery of 40 ovens, and has been permitted to submit the following notes, which include certain quotations from the specifications.

Excavations.—All bushes and trees which interfered with the construction were cut down and all roots grubbed out, until a solid bottom was obtained. Certain of the ovens required a base of concrete, owing to soft bottom being met, which was flooded with water from a spring. All the excavation was used for yard filling, not being suitable for filling the ring walls as afterwards specified.

Yard Walls.—The yard consists of a wharf, upon which the coke is piled preparatory to being loaded in box cars, the walls being made of timber cribs. The longitudinal pieces in these cribs are 10 inches by 10 inches, and the cross tie pieces 6 inches by 10 inches by 6 feet. The longitudinal pieces were made to break joints, and each joint was drift bolted with ¾ inch iron. The height of the wharf above top of rail of siding was 7 feet.

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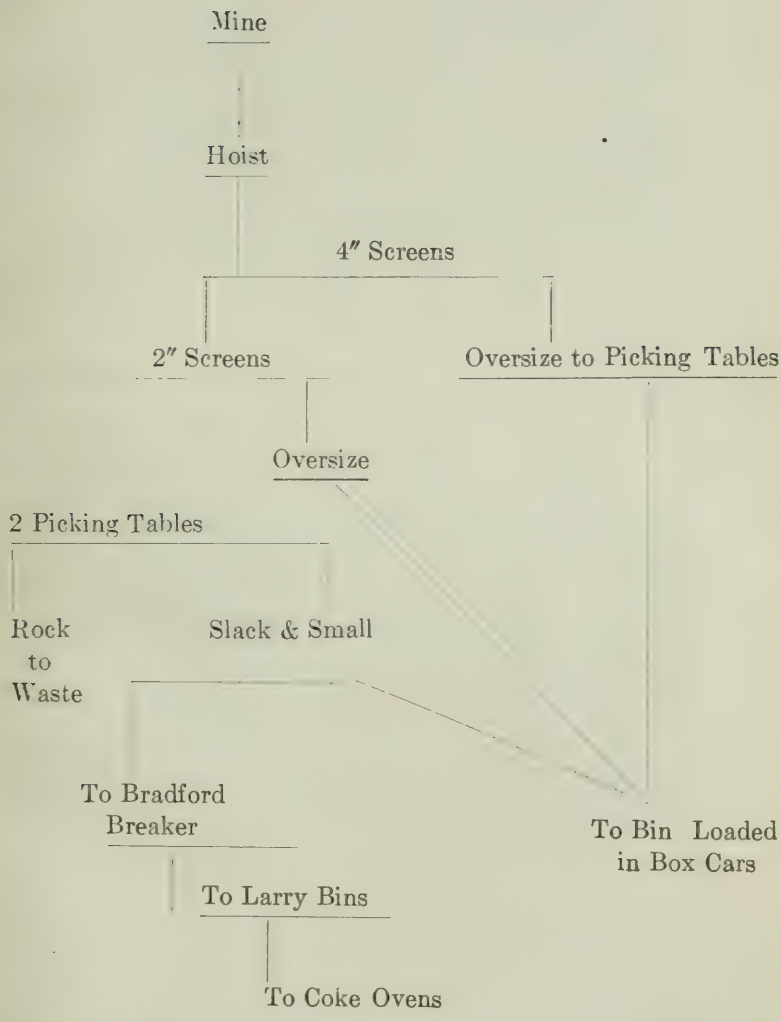
The Coke Ovens—Excavation.

The Coke Ovens—Building the Ring Walls.

FLOW SHEET OF TIPPLE.



Oven Foundation.—The ovens were laid out by a surveyor, who set out two parallel rows of hubs, 14 feet centres in both directions. These hubs are shown in one of the illustrations. The lower part of the foundation or ring wall to one foot below the wharf level was built of dry masonry. Sandstone having flat beds was used, and tests were made to avoid the employment of any stone containing lime. The stones were on an average about 6 inches thick, and one-third of those in the faces of the walls and rings were headers. Up to 6 feet high the masonry was laid 3 feet 6 inches wide, and from 6 feet to 1 foot below yard level 4 feet 6 inches thick. The remaining foot to yard level was laid in mortar.

The rings of the foundation walls were filled in with a good clay free from vegetable matter. Owing to the depth of excavation to solid ground, these rings were quite deep, and were filled with fire clay obtained from between the coal seams and foot rock.

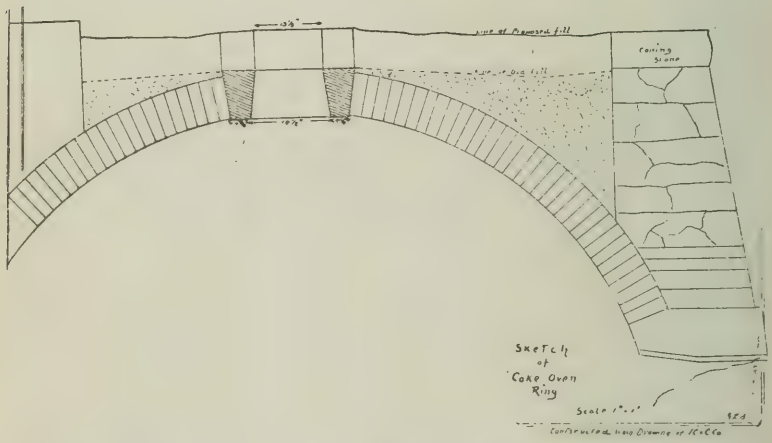


FIG. XI.—Section of Crown.

The face walls of the ovens from yard level are 11 feet in height, 3 feet 6 inches thick at yard level, and 1 foot 8 inches thick at the top, having a batter in the face of 2 inches per foot. The stones in this wall were free from lime and had flat top and bottom beds, and none was used less than 6 inches thick. One

The Coke Ovens—Ring Wall completed, before filling.

The Coke Ovens—Door Frames.

third of the stones were laid as "headers," all the top stones being through stones. All the face stones were squared up by hammer, and no spalls were used in levelling up. The stones were laid in a full bed of mortar, made from well burnt lime and clean, sharp sand. All joints were well pointed.

Larry Track Piers.—On top of the stone foundation the larry track piers were built. These are 18 inches wide by 7 feet in length, also laid in lime mortar to within 18 inches of the top. This top was capped by a stone 18 inches thick to carry the rails.

Fine Brickwork.—The following extracts from a paper by Mr. Dickson will describe this work sufficiently.

"The arch or crown starts on top of the inner wall, and is "41 courses high. The crown brick is what is known as Silica "brick, composed of coarse ground, pure silica rock, bonded with "lime or fire clay, 2% of the former and 10% of the latter being "used; the dimensions should be 9 inches long, 2–7116 inches by "3–15116 inches on small end, 2–314 inches by 4–5116 inches "on the large end; these should also break joints, half bricks "being used to effect this. Each brick before it is laid should "be dipped in a thin mixture of fire clay and water, in order to "bond the bricks as they are laid. By this means a form for "the arch of the crown is dispensed with, the whole being finally "keyed together by the trunnel head or ring at the top of the "oven. The correct curvation of the crown is maintained by "means of a revolving arm, the length of which is the exact "radius of the circle forming the crown, one end being fixed on "an upright, and the point where the arm and the upright join "is the centre of the circle."

The following is the number of bricks required to build one oven:—Crown, 2,900; liners, 1,300; red brick, 400; tile, 124; arch bricks, 7; door jambs, 8; skew backs (1 R., 1 L.), 2; eyes, 1; door frame, 1.

The jamb and arch blocks of the oven doors were laid with close fire clay joints. The oven door frames were set to the proper batter of the wall (2 inches to foot), and anchored into the wall with iron anchors.

The floor site was laid on a bed of sand of about 6 inches thick and having a fall of 6 inches from the back to oven door. The cracks in the tile were well filled with loam.

Red Brick Work.—An arch of hard burnt red brick, consisting of two rows, laid on their edges in lime mortar, and concaved as shown in the sketch, was built above the firebrick arch blocks over the door. Brickwork extending through the wall was built

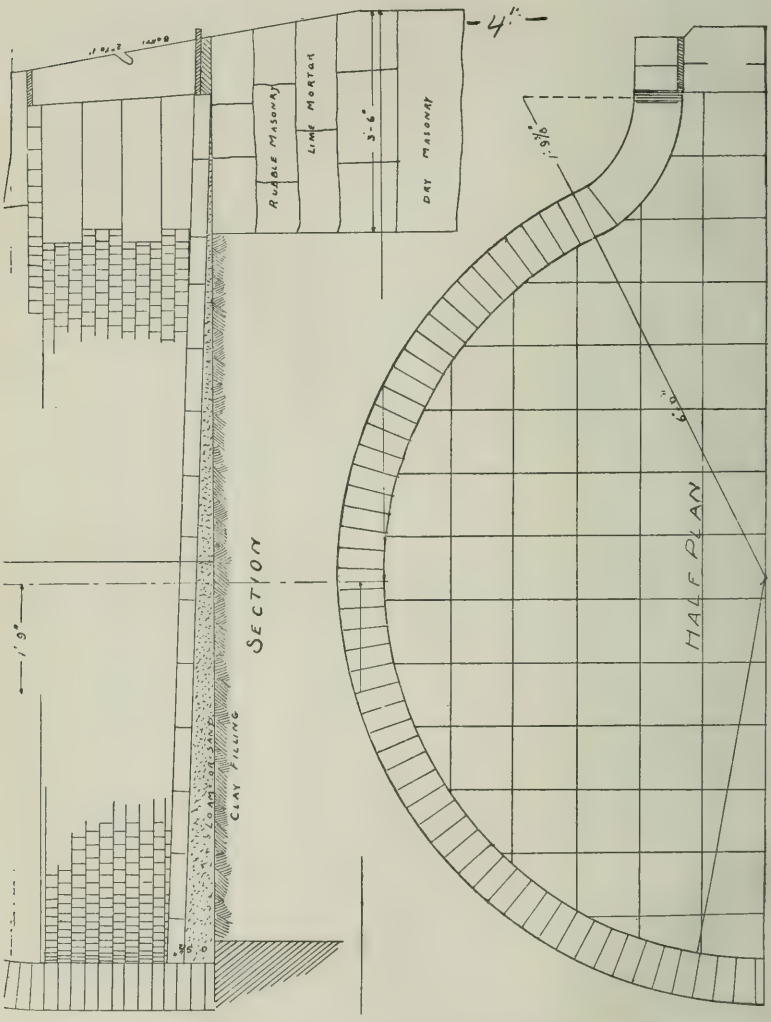


FIG. XII.—Section and Plan of Oven Wall.

from the oven seat to two courses above the top of the red brick arch. It was laid in lime mortar, and was 18 inches on each side of the door frame.

The outside of the fire brick of each oven, above the lining brick, was plastered over with a good coat of loam mortar. The filling above this inside of oven walls, above oven seat level, was deposited in horizontal layers and tamped with iron rammers.

Larry Tracks.—The ties were spaced approximately two feet apart, and two cast iron ties were laid for each oven, the rails being bolted to these.

The quantity of material used in the construction of one oven is nearly as follows:—Stone in dry wall, 22 yards, note (a); stone in mortar wall, 16 yards; lime, 1·2 yards, 0·86 tons; sand, 3·8 yards, clay filling, 35·18 yards; sand for filling ties, 2 yards; and fire clay, ·75 tons.

The larry rail is a 70 lb., is 7 inches high, and is tied with iron rods between the piers and iron ties on the piers.

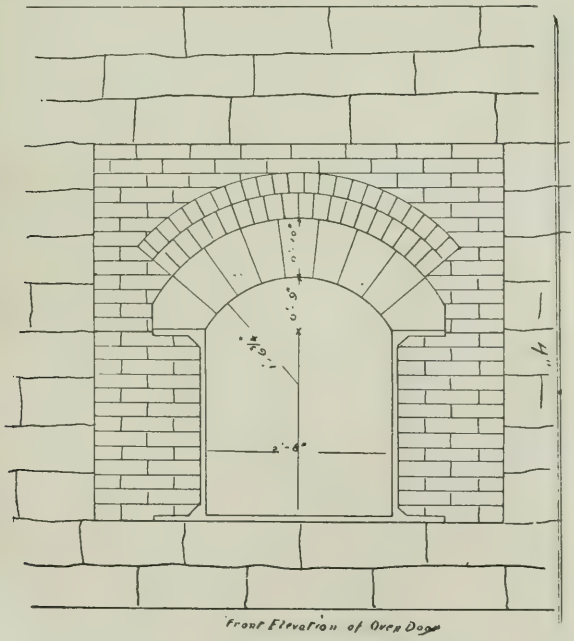


Fig. XIII.—Elevation of Oven Door.

THE WILBUR IRON MINE.*

By SHIRLEY KING, School of Mining, Kingston, Ont.

The Wilbur Iron Mine is situated at the northern end of the County of Lanark, in the township of Lavant, on lots 3 and 4, in concessions 13 and 14. It belongs to the class of ore bodies often referred to as the Eastern Ontario Magnetites. It is easily reached by the Kingston and Pembroke railway. The mine is about half a mile east of the little station of Wilbur on this road, and a short spur running directly beneath the ore bins gives access to the main line. This connection solves the important question of transportation, a consideration of paramount importance in connection with the operation of iron mines. The ore may be shipped to the smelters by an all rail route or by rail and water via Kingston.

The character of the country in the neighbourhood is typically Laurentian, by which one refers to a topography peculiar to this northern territory. It is a part of the extensive Archæn area of this continent. Climbing one of the low hills to view the prospect, one is struck by the uniformity of the landscape. All the hills appear to be of nearly uniform height, one higher than the common being exceptional, and well named a peneplain. The hills are invariably isolated, and not in ranges and most of them are bare of soil and trees. The country is cut up by little streams and lakes. The lower parts of the district are covered by marshes and beaver swamps, in many of which the huge stumps still afford evidence of former magnificent forest growths.

The immediate topography is that of a valley deeper than usual here, with hills rising on either side. It is an old river course, along which a small stream still flows. In the vicinity of the mine, the course of the valley is N. 10° E., the stream flowing south. The eastern slope of the valley is gneiss and limestone,

* Entered for 1909 Competition, and awarded honourable mention.

the entire bottom of the valley being underlaid by the latter formation. The western slope and bottom of the valley towards the north is an intermixture of limestone and crystalline schists, the latter being partly quartzose and partly garnetiferous. The difference in elevation between stream bed and top of slope at the mine is practically 100 feet. The present working lies about 40 feet up the western slope, the earlier openings being farther to the north and at a higher altitude.

The rocks about this deposit are mainly gneiss and limestone, with small areas of crystalline schists in the limestone area proper. The contact between the two main country rocks is about half way up the east slope of the valley, and follows along it for about half a mile north from the lowest workings.

Here it turns abruptly to the east. Wherever the drift has been washed away, the relation of the rocks is plainly marked. It is along this contact that the ore bodies lie. Nine workings in all have been opened on the ore and all lie along or within a few feet of the contact.

The gneiss for the most part is red, although the colour varies from pinkish to quite a dark grey. Throughout the rock area examined, however, the rock was prevailing red in colour. A hand specimen of this gneiss would be described as hornblendic, since this mineral is by far the most prominent of the dark constituents. Several little dykes were seen and traced, but did not have the true dyke characteristics; their walls not being sharply defined. They were lighter in colour than the gneiss and graded into the wall rock very gradually. Proof that they are dykes was obtained by correlating one, similar to the rest, with a dyke found in the ore body, having true walls, selvages and faulting. A smaller example was found at the northern pits, here showing the age relation of the rocks. It passed as a little irregularly defined dyke out of the gneiss into the limestone. In the latter it had clearly defined walls. Considering these as aplitic dykes and end phases of the gneiss, the limestone is shown to be the older.

The hand specimen plainly shows a well foliated rock, this structure being produced by the parallel disposition of the coloured constituents. Under the microscope it is an as even-grained admixture of quartz, orthoclase, plagioclase and micro-

cline, hornblende, biotite, titanite and apatite. Very little quartz is present and it is all allotriamorphic. Much of the feldspar is orthoclase, some of which shows Carlsbad twinning. A great deal of the orthoclase is altered to other minerals, chiefly kaolin. Under the higher power of magnification, the cleavage cracks can be seen filled with long needles of sericite. Wavy extinction evidences the effect of pressure or strain.

The plagioclase present in subordinate amount to the orthoclase does not show the polysynthetic twinning very plainly. A very little microcline is present in small grains. Common hornblende is the predominant ferromagnesian constituent. It has no definite crystal outline but is irregular in shape. It has very marked pleochroism and usually shows the characteristic prismatic cleavage. It is filled with inclusions of quartz, titanite and perfectly formed orthoclase, an example of poikilitic structure. A little biotite also occurs. Small crystals of titanite are abundant usually included in the hornblende or in the mineral near it. The characteristic wedge shaped crystals are usually more or less rounded or irregular. Small colourless crystals of apatite are present, with characteristic high relief and hexagonal form in cross section.

Another section of the gneiss, collected from nearer the northern pits was examined. This specimen had not such a characteristic gneissic structure. It was darker in colour and was obtained from near the little aplite dyke above described. The microscopical examination showed it to be composed of quartz, orthoclase, microcline, biotite, muscovite and tourmaline. The section as a whole would be described as having panidiomorphic structure. About half the orthoclase is altered to a colourless mineral giving very high interference colours, probably muscovite. All gradations from the clear unaltered felspar to grains showing complete decomposition are present in the section. One or two little crystals of microcline occur. Biotite is the prominent coloured constituent. Well formed prismatic crystals of tourmaline are scattered all through the section. The tourmaline is clearly seen to be one of the earliest formed minerals in the rock. It is distinctly bluish and as usual strongly pleochroic. A black opaque mineral occurs in two or three little pieces of irregular shape. It gives steely appearance in reflected light and a reddish

tinge around the edges under crossed nicols. The mineral is probably ilmenite.

The rock which is in one case hornblendic, in the other biotitic, is probably igneous in origin and would be classed as a granite-gneiss. An analysis of the first gneiss described above gives the following composition:—

SiO_2	63.30
Al_2O_3	15.82
Fe_2O_3	4.27
FeO	2.67
CaO	4.66
MgO	2.31
TiO_2	.71
K_2O	1.73
Na_2O	4.84
P_2O_5	trace
	100.31

The limestone wherever exposed is crystalline. In some places it is pure white marble, no sign of foreign matter being apparent. In other places it is quite impure. In a railway cutting the writer's attention was drawn to a mineral giving very bright reflection from a large surface. The mineral is pure white, and possesses a very pronounced vitreous lustre. The reflection is caused by the development of the large prism faces. Planes of parting are specially well defined.

A chemical analysis gave the following result:—

SiO_2	55.32%
$Fe_2O_3 + Al_2O_3$	3.73
CaO	24.73
MgO	16.06

This analysis indicates a pyroxene of the diopside variety.

A microscopical examination of oriented sections of the mineral also shows it to be a pyroxene. In a section almost parallel to the basal parting the cleavages cross one another at an angle of 85°. Both the index of refraction and double refraction are

high. Very minute included scales of brilliant polarizing muscovite are microscopically developed, but although numerous, they form but a very small proportion of the whole individual.

In a cutting east of the workings in the limestone, were found large dirty looking nodules of some mineral, which seemed to have resisted weathering better than the rock. A blow from the hammer simply crushed it and not until an inch or more had been pounded away, was anything like fresh looking material obtainable. It was a greenish looking material, with a greasy feel and showed parting not unlike the pyroxene described above, but not so well developed. A chemical analysis conducted upon the material then collected indicated that these individuals were diopside, which had undergone more or less decomposition to serpentine with an accompanying development of magnesium and calcium carbonates.

	Diopside (analysed)	Serpentine (pure)	Serpentinous mineral analysed
SiO_2	55.32	43.48	50.59
$Fe_2O_3+Al_2O_3$	3.73	....	1.68
CaO	24.73	....	7.17
MgO	16.06	43.48	22.66
H_2O	....	13.04	4.04
CO_2	....	....	6.20+

The limestone was seen at the contact with the ore body. With the exception of a few scales of light coloured mica it is apparently quite pure. In thin section the individual crystals in many cases show well marked rhombohedral cleavages, in which secondary calcite has been developed. The calcite occurs as long stringers, also as irregular grains and also as well defined rhombohedrons. The muscovite is present both as single crystals and in aggregates.

Across the valley and about half a mile up it, certain schistose rocks occur, some of which are very silicious; others are garnetiferous, the individuals varying from $\frac{1}{4}$ inch diameter up to $1\frac{1}{4}$ inch diameter. These are commonly present in the more micaceous layers.

Evidences of metamorphism are many, the present composition and attitude of the country rocks themselves being the best testimony of such action. Detailed descriptions of similar or

closely related rocks may be found in the reports of Logan, Hunt, Adams, Barlow and other Canadian geologists. Secondary minerals are very numerous, and among these are diopside, garnet, muscovite, talc, asbestos, actinolite, and bornite. Contortions and foldings are sometimes observable.

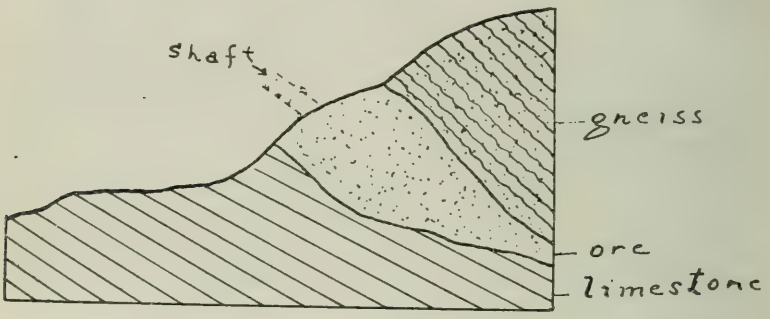
A beautiful example of a fault occurs in the mine. The dyke described above as cutting the ore body is faulted for about 15 feet, and with a strike of N. 60° E., dips at an angle of 45°. In the first level is seen the plane of the fault which inclines about 7° to the horizontal. It is marked by a vein of gouge, about 10 inches thick and composed of dark green chloritic looking material.

The ore itself, is a hard compact close grained magnetite, and has not the coarsely crystalline characteristics of many of these Ontario magnetites. Calcite and probably dolomite is intermixed with the ore throughout. Layers of chlorite from half an inch to six inches or more in thickness occur in the ore body. Chlorite also occurs on the footwall and also forms a selvage on the intruding dyke. Stringers of calcite serve to give a laminated appearance to some of the ore. These stringers or rather layers vary from the thickness of paper to a quarter of an inch in width, one large layer noticed measuring four inches across included scales of very dark mica. Much of the ore even when freshly broken exhibits little red patches presumably of hematite. One yellow nodule of limonite was also collected.

The ore body occurs in the form of separated masses along the contact between the limestone and the gneiss, already described, From the evidence obtained by diamond drilling and other mining operations, it would appear that the deposits are lens-shaped. The deposit now being worked as a large open pit, is typical. At the surface the ore-body is 28 feet wide, but at the first level increases to 32 feet, thence downward gradually narrowing, until at the bottom of the workings it is only two feet across. The depth of the deposit in the direction of the workings is, so far as known about 350 feet. The length of the deposit along the strike is at least 200 feet. The subjoined figure illustrates the mode of occurrence.

The ore is nearly free from deleterious constituents found in some of the Eastern Ontario magnetites and runs very high in metallic iron.

According to Mr. E. D. Ingall, of the Geological Survey of Canada, these magnetites contain an average of 0.022% phosphorus. This was the result of thirty-seven determinations, the variation being from a trace to 0.17%. Ten assays for sulphur contents gave an average of 0.58%, the range being from a trace to 1.75%. Of twenty-five determinations for titanium this



Sketch of section through ore body at shaft.

element proved to be absent in thirteen cases; present, but not determinated quantitatively, in two others, and in the ten other cases, present, in percentages varying between 1.03 and 16.45.*

The analysis of the marketable ore is as follows:—Fe 55.49, Insol. 3.45, Sulphur, 0.04, Phosphorus, O .022.†

Following the classification of Pre-Cambrian rocks, adopted by the Correlation Committee, the following geological formations are exposed in the immediate neighbourhood of this mine:—

Cenozoic.	Recent.
	Glacial.
Pre-Cambrian .	Laurentian—Granites and gneisses.
	Grenville—Hastings series: Crystalline limestone and schists.

The ores occur in these earliest of known rocks.

In connection with the origin of the Ontario magnetites various theories have been advanced, which may be grouped as follows:

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* An. Rep. Geol. Sur. Can., vol. xii, 1899, part i, pp. 16 and 17.
† Ann. Rep. Bureau of Mines, 1908, G. C. MacKenzie, p. 225.

Sedimentary origin...	Beach sands accumulation.*
	Metamorphosed bog iron ore.†
	Metamorphosed beds of spathic ore or hematite.‡
	Replacement of limestone.
	Lake Superior type.**
Igneous origin.....	Pegmatite type.††
	True veins.[1]
	Concentration of ores by hot meteoric waters from adjacent rocks.[2]

Mr. F. J. Pope who made a study of these deposits classified them as follows:—[3]

1. Ore bodies where the magnetite occurs in lenses or as impregnations in schistose or gneissic belts. In most of these instances limestone is altogether absent or only occurs at some distance from the deposit.

2. Ore bodies occurring in belts of crystalline limestone immediately at their contact with the harder gneissic and schistose members of the series.

3. Ore bodies titaniferous in character occurring entirely in the anorthosite and basic gabbros. This body then clearly belongs to class two above.

The beach accumulation theory.—Magnetic sands were concentrated on beaches in the pre-historic seas. These have been later metamorphosed by overlying formations and lateral pressure. The chief argument advanced in favour of such an origin is that the ores of certain deposits can be separated into magnetite and ilmenite by mechanical means. The Wilbur deposit, however, contains very little titanium. Further, quartz and garnet sands are the invariable accompaniment of magnetic sands deposit, but these minerals do not occur as a part of this ore-body. In addition such deposits show wide variation in composition. The Wilbur deposit, however, is practically uniform.

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* & † J. B. Harrington, Report of G.S.C., 73–74, p. 195.
‡ Phillips & Louis, Ore Deposits, 1896, p. 535.
** & †† C.M.I., 1908, Leith.
[1] Geol. Sur.Can., vol. iii, 62–64, part S.
[2] Bull., No. 338., U.S.G.S., Leith and Harder.
[3] A.I.M.E., vol. xxix, p. 372.

Metamorphosed bog iron ore.—This theory was advanced by Harrington. As evidence in support, he describes an experiment in the laboratory whereby bog iron ore was changed to magnetite simply by the application of heat.

Metamorphosed beds of spathic ore hematite.—A deposit is described in Philip's and Louis' "Ore Deposits," which is very similar to this one, save that it also contains manganese. These writers suggest that the bed may have been deposited as spathic iron ore or hematite, which has been subsequently metamorphosed to its present condition.

Replacement of limestone.—Kimball has written much on the subject of replacement. The presence of calcite throughout the ore might be advanced in support of such a view regarding the origin of the Wilbur ore body. But wherever we find the replacement of a country rock in progress, we find extremely indefinite boundaries, the absence of which is characteristic of this deposit.

Prof. Leith in his paper last year before this Institute, referred to this class of deposit as possibly being the explanation of some Ontario deposits. He says that, "It is obvious that gradation phases are to be expected between the Lake Superior type and pegmatite type and that many ore deposits can with difficulty be assigned definitely to one or to the other." Accepting this as an explanation of the origin of this case, the history of the deposit would be something like the following: "The iron was deposited as a chemical precipitate in ferrous and ferric states together with an intermixture of silica. Leaching and oxidation eliminated the ferrous compounds and silica. Metamorphism altered the hematite and limonite to magnetite." Such deposits represent concentrations of the iron formation in their particular locality. No such iron formation, however, has been reported in the vicinity of this deposit.

Pegmatite type.—While Prof. Leith places some of the Eastern Ontario deposits in this class, the Wilbur deposit seems to be essentially different. He defines the pegmatitic type "as a deposition from essentially aqueous solutions, mixed in varying proportions with solutions of quartz and silicates. The essential features of these deposits are their highly crystalline magnetic character, their content of garnet, amphibole and other silicates, local abun-

dance of sulphides and of apatite." The contents and character of such ore then is different to what we find at Wilbur as described above.

True Vein type.—There is little or no evidence that the deposit originated in this manner.

Concentration from adjacent rocks by hot meteoric waters.—In opposition to this origin, an examination of the gneiss shows no iron ore or very little scattered through it, to serve as a supplier of the magnetite. Leith and Harder, in Bulletin No. 338, U.S. G.S., says: "It is usually where the ores are hard crystalline magnetites and hematites, intimately associated with the arhydrons silicate and adjacent to or within igneous rocks that there is reasonable probability that the origin of the ores may be ascribed to the hot solutions coming from the igneous rocks."

SUMMARY OF CONCLUSIONS.

The gneiss in the vicinity of the Wilbur deposit is younger than the limestone.

The ore is cut by a dyke, which probably represents the end phase of the gneiss intrusion. Hence the ore body is at least older than the dyke and probably older than the original rock from which the gneiss is derived.

The writer is inclined to the view that the ore-body has resulted from sedimentary deposition with later metamorphism. The reasons for this opinion are as follows:—

The ore bodies are, in general opinion, separated lenses, apparently the result of very pronounced autoclastic action, causing the separation of a layer or bed originally continuous.

Junction between the ore body and the enclosing rocks is very sharp and distinct, with little or no evidence of mutual reaction.

The absence of a coarsely crystalline texture of the ore, characteristic of pegmatitic magnetites such as that of the Robertsville mine, may at least be taken as negative evidence.

The little patches of hematite already described may be taken as representing the last surviving traces of the original hematite.

CHROME BEARING PERIDOTITES OF LAKE ABITIBI.*

By H. T. WHITE, School of Mining, Kingston.

The existence of chrome bearing rocks in the Lake Abitibi district has been known since 1872. In his report of that year Mr. Walter McOuat † of the Geological Survey of Canada gives the following description of the occurrence:—"Off a prominent point, about the middle of the west side of the lower lake, there is a small island, not more than six or eight chains long, which is composed of a dark green, rather soft rock with splintery fracture and resinous lustre, and weathering a dull white. It is so strongly magnetic that our compasses were found to be quite useless on this island. The rock proved to be a serpentine—and was found to contain chromic iron." Three years later Dr. Bell examined outcrops of serpentine exposed on portion of the shore and some of the islands of Montreal River. He describes the rock occurring on one island as a very dark green serpentine with strings of calcite and chrysotile. Fresh fractures have a somewhat mottled appearance, and occasionally present surfaces of finely columnar, shining aspect. The natural surface has a rough or "lumpy" character and weathers to a rusty colour.‡ On analysis this serpentine was found to contain oxide of chromium both in the form of small grains and in chemical combination with the rest of the rock, thus resembling the serpentines of the Quebec group.

During last summer while working in the neighbourhood of the lower Lake Abitibi, Mr. M. B. Baker, of the Ontario Bureau of Mines, discovered a somewhat similar rock to those described by Mr. McOuat and Dr. Bell. The outcrop consists of a point about a hundred yards long, and perhaps half as wide, on the east side of North East Bay of the Lower Lake and about two and a half miles by water to the nearest station on the new Trans-

* Student paper entered for 1909 Competition and awarded honourable mention.

† Ann. Rep. Geol. Surv. Can., 1872–73, p. 128.

‡ Ann. Rep. Geol. Surv. Can., 1875–76, p. 304.

continental railway. The surrounding rocks are typical Keewatin greenstones or amphibolites. As in the case of the island described above, the rock is strongly magnetic. It is a dark greenish phanerite with a rough fracture and numerous black, metallic facets of magnetite showing. A characteristic feature is the presence of knots of green serpentine which have retained the outward form of the olivine crystals from which they are derived.

Under the microscope the rock is seen to be about three-fourths fibrous serpentine pseudomorphs after idiomorphic olivine. Scarcely a vestige, however, of the original olivine is left. In some cases the serpentine fibres extend almost completely across the space originally occupied by the olivine; in other instances the fibres seem to have formed at right angles to cracks, or to project inward from the periphery. Magnetite is abundant, both in distinct crystals and grains, and in bands outlining the original olivine crystals; again sometimes this mineral occurs in streaks amongst the serpentine fibres as if it had been liberated from the olivine during the process of alteration. Filling the interspace between these pseudomorphs of olivine, and to some extent intermixed with the serpentine fibres, are aggregates of a colourless mineral with bright interference colours, resembling calcite, but which from the scarcity of lime, as shown by analysis, is believed to be mostly magnestite. Opal and chlorite occupy somewhat similar positions to the magnesite. Other minerals present are talc in small grains and veinlets; chromite in grains and dust-like particles; hematite or perhaps picotite in brownish or reddish particles. The rock is therefore a dunite, variety of peridotite in an advanced stage of alteration.

Chemically the rock is unique in its high percentage of chromic oxide. An analysis of a sample is here given for comparison; analyses of several other samples of closely related rocks from various localities are also here tabulated:—

	I.	II.	III.	IV.	V.	VI.
SiO_2	35.05	34.591	41.89	44.99	40.11	40.18
TiO_2	.50			.97		
Al_2O_3	.73	2.391	trace	5.91	.88	1.35
Cr_2O_3	6.72	.382	.58	.25	.18	1.41
Fe_2O_3	9.05			3.42	1.20	10.97
Fe O	5.08	8.660	7.39	8.30	6.09	
CaO	.54	3.625	.06	8.79	.11	
MgO	33.09	32.253	49.13	21.02	48.58	43.84
Na_2O				.91		
K_2O			.82	.74		
CO_2	1.54					
Mn_2O		.244				
H_2O	8.47	17.524	.35	3.82	2.74	2.01
K_2O			.82	.74		
	100.77	100.000	100.22	99.12	99.89	99.76

I. Serpentine from Lake Abitibi.
II. Serpentine from Pigeon Lake, Montreal River (Can. Geol. Survey).
III. Peridotite, variety, duenite, from North Carolina (N.C.G.S.).
IV. Peridotite from Michigan.
V. Peridotite from North Carolina (N.C.G.S.).
VI. Dunite from North Carolina (N.C.G.S.).

It will be seen that, aside from the specimen from Lake Abitibi, the highest percentage of chromic oxide is 1.41 and that is the highest found in quite a number of analyses. None of the serpentines or peridotites from Maryland, show any notable amount of Cr_2O_3, seldom over 0.5 per cent. The part of the intrusion from which the sample is taken, however, has something to do with the amount of Cr_2O_3, which shows a tendency to segregation near the contact with the country rock.

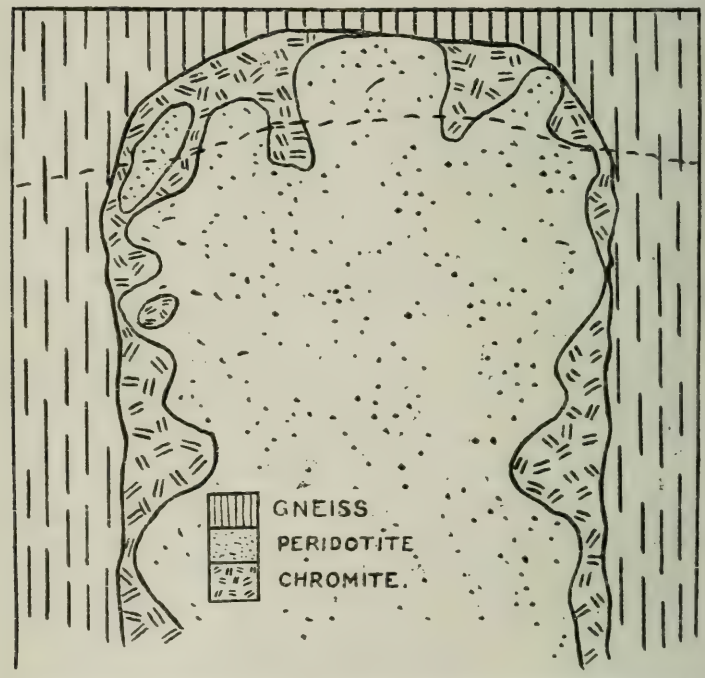
The extent of the serpentine area in the Lake Abitibi district is as yet unknown, but judging from the distance between the known outcrops and the occurrence in other districts, it might be expected to be considerable. The intrusions are small, as in other areas. A chromiferous peridotite area in Southern Quebec extends over a stretch of territory twenty miles long and of varying width. Here the peridotite is surrounded by Laurentian granites chiefly. Scattered at intervals along the central axis

of Archæan crystalline gneisses and other rocks, from Alabama to Gaspé and Newfoundland, are peridotites and the allied rocks, troctolite, olivine gabbro, amphibolite, diorite, anorthosite, etc. The majority of the intrusions are small dykes or elongated masses, the direction of elongation being parallel to the bands of the enclosing gneiss. At various places in this area the peridotites, especially the dunites, carry chromite or corundum. Where the one occurs, the other is very generally absent. Serpentines and peridotites are found in other parts of the United States, e.g., in California, Oregon and Michigan, all quite similar to those mentioned.

The likelihood that the serpentines of New Ontario may bear chromite in economic quantities may justify a short resumé here of the occurrence of that mineral. So far, chrome ore has been found only as basic segregations near the border of peridotites or their alteration product, serpentine, with perhaps some accumulations from the decomposition of these. The peridotite magma, like magmas in general, seems to have been a liquid composed of minerals mutually dissolved in one another. The more basic minerals like chromite, corundum and spinel, being less soluble separate out first according to the general law of cooling magmas. Since the cooling takes place most quickly around the edge, the basic oxides begin to separate out here first; fresh material is constantly being brought from the more central parts by convection and diffusion, thus bringing about a segregation of the chromite. If there were sufficient alkalies and silica, the alumina would go to form feldspars as is the case in most igneous rocks. When there is but little chromite, it has a tendency to rather even distribution throughout the rock mass. Immediately along the contact with the enclosing rock quick cooling frequently takes place, giving no time for the segregation of the chromite; or the temperature may be such that the corundum may crystallize out before the chromite when both are present, in which case the former will be found nearer the contact than the latter.

On this hypothesis is readily understood the occurence of chromite,—the apparently unconnected pockets from which shoot off stringers; the widening and pinching out of the pockets; and the grading of the chrome ore into peridotite.

Experience has shown that in looking for chromite, the prospector should confine his energies chiefly to peridotite or serpentine and near to the contact with the surrounding rocks which is always sharply defined. The diagram below will make clear the relations of the rocks to the ore and the reason why the outside of the serpentine is more likely to carry chrome ore bodies than the centre. The prospector may find it worth while also to watch for fibrous serpentine or asbestos which occurs in small veins seldom over three or four inches in width, in peri-



Ideal vertical cross-section of a chromite-bearing mass of peridotite after its intrusion into gneiss. The upper part has been removed by erosion.

dotites, the fibres lying at right angles to the walls. The mineral, however, has considerable value which compensates for the narrowness of the veins. The fibrous serpentine seems to have originated from olivine which has dissolved out of the peridotite, become hydrated, and deposited in fissures. Other minerals of economic value found in these rocks are corundum, the green nickel ores

garnierite and genthite, and platinum. Corundum in North Carolina occurs* chiefly in peridotites but smaller amounts also in amphibolite dykes, gneisses and schists. It is characteristically found as segregations close to the contact of the peridotite with the surrounding rocks or as pockets within the peridotite. Garnierite is found in large quantities associated with chromite in New Caledonia and a little occurs similarly in Oregon and North Carolina. In several instances platinum has been traced to its source, which seems to be almost invariably more or less serpentinous rocks. In Russia, from which the greater part of the world's supply of platinum is derived, the metal is associated with chromite in placers and has also been traced to the parent peridotite in some places. This also applies to British Columbian† platinum, small quantities of which have been found in the gravels of some of the tributaries of the Tulameen River in the Similkameen district.

By reason of the irregularity and disconnected character of the chromite ore bodies, and of their small size in very many instances, chrome mining has always been a somewhat hazardous undertaking in America. The competition, too, of foreign countries, especially that of New Caledonia, Russia and Greece has had a depressing effect on the local industry. It is said that the Turkish deposits alone are sufficient to supply the world for years to come, but at present the transportation difficulties are adverse. Any fair sized body of ore, however, if favorably situated, should warrant exploitation. For furnace linings, etc., the ore is required to be of about 50 per cent. chromic oxide, but it may be concentrated from as low as 10 per cent. Theoretically chromite has 68 per cent. Cr_2O_3 and 32 per cent. FeO; but it almost invariably forms isomorphous mixtures with magnetite and spinel. Just now the attention of prospectors and mining men is focused on the silver area, to the neglect of the lesser industries. The rewards awaiting pioneer effort in these directions in New Ontario may, however, be very considerable.

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* North Carolina Geological Survey, Vol. I. 1905.
† C. M. I. Rep., Vol. VII., 1905, p. 192.

COAL MINING IN PICTOU COUNTY, NOVA SCOTIA.*

By J. R. RUTHERFORD, McGill University, Montreal.

The Pictou County coalfield occupies a valley between two prominent hill ranges lying east and west, and is drained, principally, by the East River, which cuts the field at its most productive point. To the east and west, at the extreme boundaries of the field, the land rises to an elevation of about 250 feet above sea level.

In Part B of the Report of the Geological Survey of Canada, Fletcher gives the following classification in descending ores:

Permian	Upper red sandstone and shale group with thin band of limestone. Middle grey sandstone and shale groups with small coal seams. New Glasgow conglomerate.
Carboniferous	Coal measures. Millstone Grit. Carboniferous limestone. Carboniferous conglomerate.
Devonian	Upper red slate and shale group. Middle grey slate and shale group.

FAULTS.

†The most interesting feature of this coalfield is the series of faults, which traverse the measures in two directions. Some of

* Student paper entered for 1909 Competition and awarded honourable mention.

† Extract from "The Pictou Coal-Field, Poole."

the more important faults are:—the McCulloch Brook fault, the Fletcher fault, the North fault and Potter's fault. The extent and position of these faults is shown in the map accompanying Dr. H. S. Poole's report on the Pictou Coal Field.

McCulloch Brook Fault.—This fault has left its impress on the face of the country to-day, the depression to the west corresponding with the down-throws, while on the eastern side of the Westville section the thrust of the adjoining anticline is crowned by a hill. This fault is now given as over 2,000 feet, and marks the western extremity of the Albion section.

Fletcher Fault.—This fault is a large one. It divided red and grey rocks, dipping at a light angle to the northward from the coal measures, dipping S. 40°, E. 13°.

It hades to the north with a width of 130 feet, and inverts the lower of the strata it disturbs.

North Fault.—Directly north of the supposed limits of the field is a heavy conformation, known as the New Glasgow conglomerate, and the field here is cut by the extensive north fault, which marks the division between the conglomerate and the coal measures. Whether this fault entirely cuts out the coal measures, as yet remains undetermined.

Potter's Brook Fault.—This fault is marked where the bottom of the basin is supposed to be, and now appears to be only local, marking, on the east side of the river, the separation of the Albion series of measures from those of Potter's Brook section on the north side of the basin.

Division of the Field.

The coalfield may be divided into separate sections, having the following limits:—

The Westville Section, to include all the coal-bearing strata lying west of McCulloch's Brook and Water's Hill;

The Albion Section, succeeding to the eastward as far as the Intercolonial railway bridge, and the mouth of Potter's Brook;

The Potter's Brook Section, from the points mentioned on the East River to the town of New Glasgow;

The Fraser Adit Section, lying eastward of New Glasgow and the last named section.

The McLellan's Brook Section, an overlying extension eastward of the Albion.

The Marsh Pit Section, the further continuation of the series upwards, including the highest in the middle coal formation;

The Vale Section, which takes in the most eastwardly lying portion of the field, and its extension westward on the flanks of McLellan's mountain to McLellan's Brook forms;

The Mountain Section, which completes the area of these deposits so far as is known.

COMPANIES OPERATING IN THE SECTION.

The principal coal areas are held and operated by the following coal companies:—

Intercolonial Coal Mining Co. Ltd., 9 square miles, operating at the Drummond Colliery, Westville; N. S. Steel & Coal Co. Ltd., $\frac{3}{4}$ square mile, operating at the Marsh Mine, Coalburn; Acadia Coal Company Ltd., 16 square miles, operating at the Acadia Colliery, Westville; the Vale Colliery, Thorburn; the Allan Shafts and the Albion Colliery, Stellarton.

ALBION SECTION.

The writer would here call attention to the Albion section of the field, and more particularly to the underground workings of the Albion Colliery.

This section extends from a point five chains west of the west corner of the lease of four square miles, known as the Albion area, thence across McCulloch's Brook and across the East River, without a dislocation of serious moment, as far as a point 23 chains N. 80 W. from the south corner of the same area; here its continuity is lost.

There are four great coal seams in this section, namely:—the Ford, or main seam; the Cage, or deep seam; the Third seam; and the McGregor seam.

The thickness of coal in these seams varies from 40 to 50 feet, in the Ford seam, to 10 to 15 feet each in the other seams. As shown in Fig. I, these seams underlie and run about parallel to one another; the dip varies from 19° to 23°, at the outcrop, to 0° at basin, and is as high at 80° on the opposite side of basin.

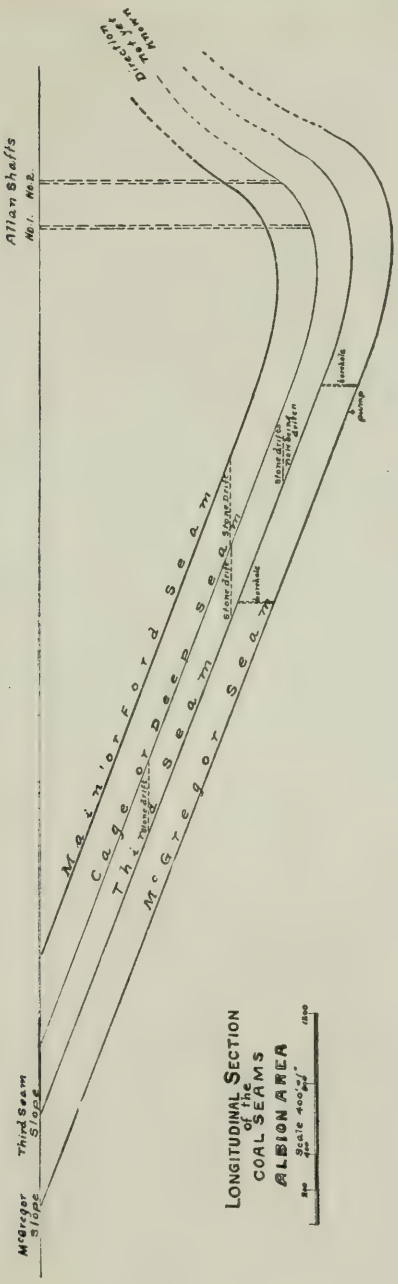
Direction of Rivers
Allan Shafts No. 1 & 2
Main or Ford Seam
Cage or Deep Seam
Third Seam
McGregor Seam
Third Seam Slope
McGregor Slope
LONGITUDINAL SECTION OF THE COAL SEAMS ALBION MINES
Scale 400 feet to 1 inch

FIG. 1.

Between the Ford and the Cage seams, but very close to the latter, there is a smaller seam, known as the "Longwall"—from the method of working it. This seam ranges from 4 to 6 feet in thickness. Near the basin the strata between Longwall and Cage seams disappear, and the Cage seam there has a thickness of over 25 feet.

The Ford or Main Seam.—The Ford or Main seam was first developed in 1866 by means of a shaft. In 1880 an explosion occurred, followed by fire, and to save the mine the East River was tapped and the mine flooded. In 1890 the water was pumped out, and an attempt made to develop the lower section of the seam; but, owing to trouble from old fires, the attempt was unsuccessful, and the mine was once more flooded, and has not since been re-opened. To-day the seam is worked at the Albion Colliery (as yet not to any great extent) and at the Allan shafts. The latter were sunk about four years ago. No. 1 shaft, 1,500 feet deep, was sunk to the Cage seam. No. 2 shaft, 200 feet to the north of No. 1, 1,000 feet deep, was sunk to the Ford seam. The thickness of the Ford seam here is said to be over 48 feet.

The McGregor Seam.—The McGregor seam is not directly connected with the others. A slope, sunk from the outcrop, extends to the basin, a distance of over 5,000 feet. This seam has been almost worked out, the pillars only remaining to be drawn—an operation which, by reason of the proximity of the other seams, must necessarily be deferred until all the overlying seams have been worked out.

The Albion Colliery.—The Albion Colliery, operating mainly the Third and Cage seams, is situated about one mile from the town of Stellarton. A railway runs from the colliery to the Allan shafts ($1\frac{1}{4}$ miles), where connection is made with the Intercolonial railway.

The Third Seam.—The Third seam was originally reached and operated by means of two slopes, Nos. 1 and 2, sunk from the outcrop and about 50 feet apart. In 1890 an explosion, followed by fire, occurred in the No. 1 mine; the old workings were walled off, connection made with the No. 2 slope, and to-day No. 1 slope is used as a part return airway for the west side, and the seam is worked entirely by means of No. 2 slope. A back head or trav-

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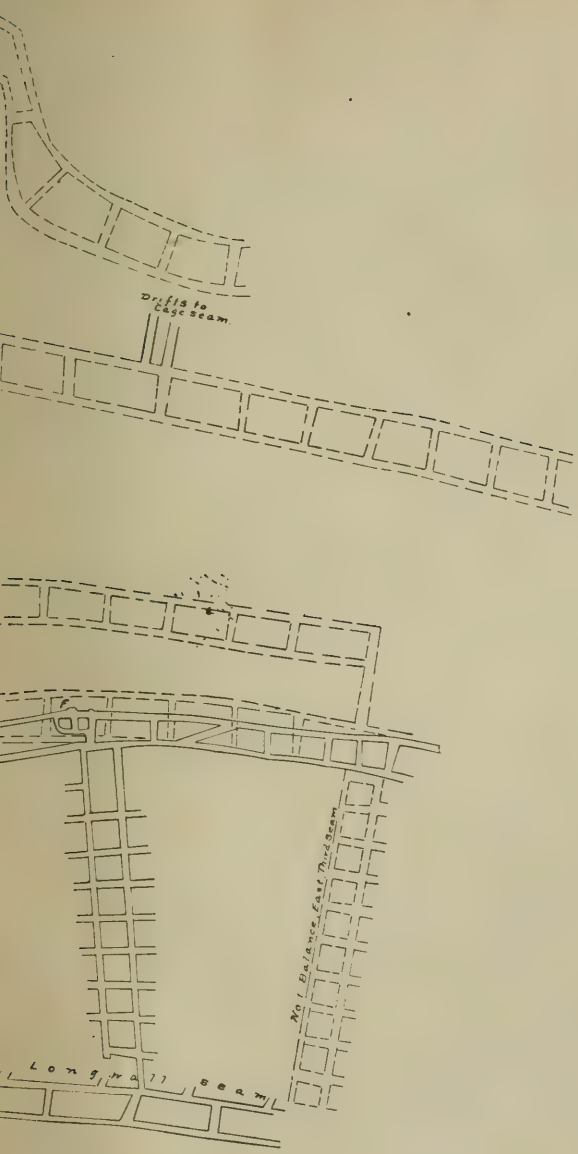
branch-
empty"
Fig. 2,



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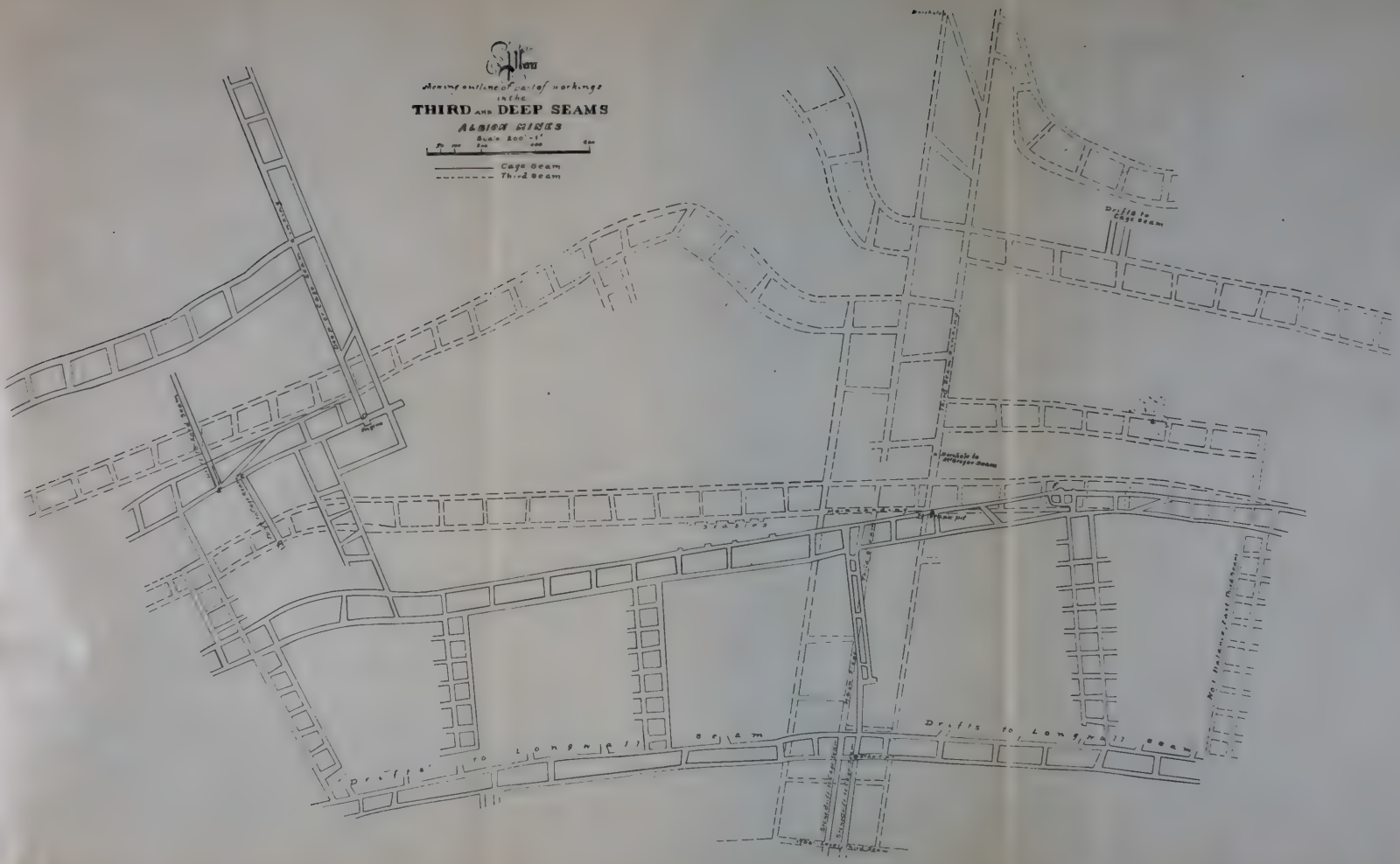
Plan
showing outlines of parts of workings
in the
THIRD AND DEEP SEAMS
ALBION MINES
Scale 200 ft
Cage Seam
Third Seam
Drifts to Cage Seam
Drifts to Third Seam
Drifts to Long Hill Seam
Drifts to Long Hill Seam

FIG. 3.

elling way to No. 2 slope was driven about 100 feet to the east; this also serves as a return airway for the east side.

This main slope (No. 2) of the Third seam, is laid with three rails, with a turn out at the centre and two double tracks branching east and west at the bottom landing, where the "empty" tracks are raised two feet above the level. Referring to Fig. 2,

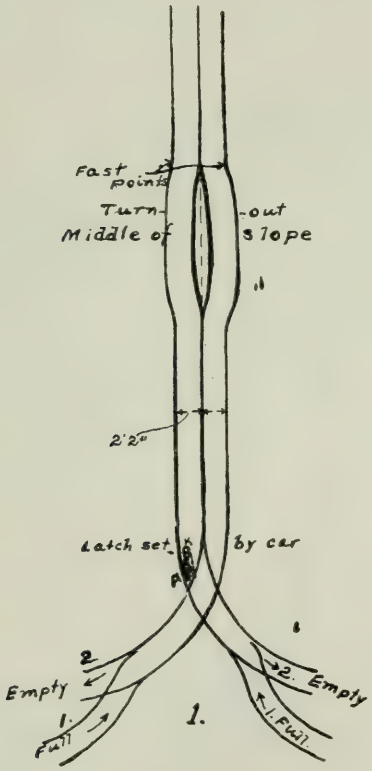

FIG. 2.
Main Slope, Third Seam, arrangement of tracks.

the empty rake (a rake consists of nine one-half ton boxes) takes the high road, either for the east or west side; the chain is then hooked on to the full rake, which stands on the main level; by means of "A," a self-acting switch, the full rake always takes the same road as the previous empty. This switch "A" merely con-

sists of a long, stout block of wood, protected by iron bands, and swings through a small arc about the pivot K.

As required by law, manholes are placed every 66 feet on this slope.

About 200 feet from the bottom landing (see Fig. III), the Third seam sinking, along with a backhead, was driven to the basin. Levels were driven east and west, but owing to the peculiar twists and turns the coal seams assumed, the work was stopped for the time being. At No. 4 east level two level drifts are now being driven to the Cage seam.

About 2,000 feet west of bottom landing, main level ("A" on plan), a level stone drift or tunnel, about 75–100 feet long, was driven to the Cage seam.

The Cage or deep seam.—From the old landing 1,700 feet down the main slope of the Third seam, two level stone drifts were driven to the Cage seam. In No. 1 drift there is a single track, which, by means of a draw-bridge, can be connected to the main slope track. No. 2 drift is used as a return airway.

On what is known as the "Iron Door Level" of the Cage seam (see "B" on plan), a staple pit or shaft 130 feet deep was sunk to the Third seam. The foot of this shaft is on the main level, east, Third seam, about 200 feet from the slope. The coal from the rise workings of this seam (i.e., the workings on and above this level) is lowered down this shaft to the Third seam, and thence hauled to and up the Third seam slope.

The means of operating this staple pit are simple and are readily understood by reference to Fig. 4. A drum 3 feet in diameter, 5 feet long, was placed on the level above, and from here a level crosscut was driven to the top of the shaft. Two wire ropes are wound in opposite directions around the drum. One of these ropes is attached to the cage, the other to the counter balance. Around one end of the drum is an iron cleating, 6 inch side, with 4 inch flanges. In this groove lies the brake—an iron band—which, by means of a long lever, can be tightened or released by the shaft boy standing at "B." The full box is shoved on the cage at the top of shaft, the brake released, and the weight of the full cage descending brings up the counter-balance; the empty is now put on at bottom and the descending counter-

balance brings it up. About 200 boxes of coal are sent down in this way every shift.

At ("C" on plan) where stone drift from the Third seam enters the Cage seam, levels were driven east and west, and at "D," a sinking (i.e., a slope sunk underground and not extending to the surface) was driven to the basin. Backheads or counter-levels are always driven parallel and at the same time with the levels and sinkings.

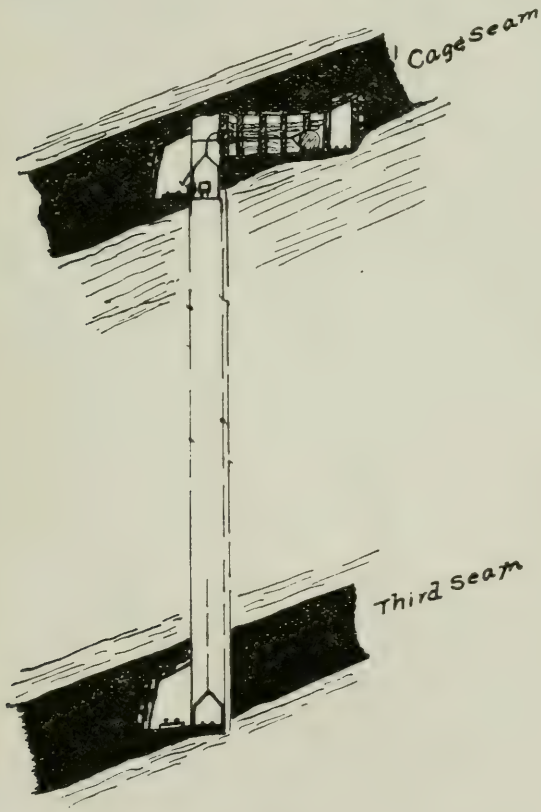

FIG. 4.
Section of Cage and Third Seams showing operation of Staple Pit.

Ford or Main Seam.—At ("E" on plan) about 100 feet west of the Third-Cage seam drift, a drift was driven to the Ford seam. The workings in this seam are not, as yet, very extensive.

METHODS OF MINING.

Balances.—Bord-and-pillar work by means of self-acting planes or balances, with rooms or bords driven to the rise of main levels, is the system employed in mining the coal. The balances are driven 10 feet wide and usually 400 feet apart. A backhead for the purpose of completing the air circuit is always driven along and parallel with the balance. These backheads are 9 feet wide, and distant 45 to 50 feet from the balance, depending to a large extent upon the nature of the coal and the amount of gas present. The balances are equipped as self-acting planes. A drum is placed at the head of the balance. Two wire ropes are wound in opposite ways around this drum, one attached to the cage, the other to the ballast box. The drums are built out of 3 inch spruce, having bevelled edges, so as to make close joints. In the centre is a 3 inch hardwood flange, which keeps the two ropes separated. On the cage side of the drum is the brake, which consists of an iron band, tightened or released by means of a lever operated by the brake boy. The balance box runs on a 16 inch track guage, and is made of two 4 inch by 1 inch iron bars bent so as to form a carriage, which carries sufficient cast iron weights of 125 lbs. each to over balance the empty box. The cage road is made a regular grade, and laid on the pitch of the seam; the ballast or balance box road is slightly steeper at top and foot of balance; this in order to insure a good start. When the pitch of the seam is as steep as 28° or 30°, chutes are used in place of balances.

Bords or Rooms.—Level bords or rooms 12 feet wide are driven off the balance every 50 feet, but usually only on one side. This is known as the single balance. In double balances the bords are driven off on both sides, but these balances do not work satisfactorily. The most satisfactory single balance has been found to be one which runs for eight bord lengths. Starting at 1 bord and by unloading each bord consecutively, by the time No. 8 bord is unloaded, No. 1 will be ready again for the cage. The bords are single tracked; a "cope-up" for the empty box being dug in the high side rib, near the entrance.

When the bords have been driven in their full length, the pillars are started back. In drawing a panel of pillars, all the coal is taken out, the roof being allowed to crush as the work

proceeds, and the working face of the top pillar being always kept in advance of the one below.

Levels.—The levels are generally driven 8 feet wide and at a grade of about 1 in 140. They widen to 11 feet at the foot of balances, where turnouts are placed. At every 100 to 130 feet, heads 6 feet wide are driven from one level to its backhead or counter-level for the purpose of forming an air circuit. Faults with down-throws and up-throws of the coal are frequently met in driving the levels. The method of again striking coal is as follows:—

The seam dips to the north; if a down-throw occurs on a level being driven east, the level is turned to the south. If an up-throw occurs, the level is turned to the north. The reverse of the above method is followed for levels driven west.

Longwall.—The longwall system of mining is used at the Acadia mine, Westville, where, owing to the depth, the weight on the deep workings greatly interferes with mining the coal by the bord-and-pillar method. The longwall system was employed in the working of the Longwall seam, as already stated, and to-day is also successfully employed at the Vale Colliery, Thorburn, and at the Drummond Colliery, Westville.

The Mining of the Coal.—The Albion coal is soft and generally easy to mine. A parting, "the mining part," extends across the centre of the working face; this is mined in by pick from 5 to 6 feet; holes are then drilled in the top and bench and charged and fired by the shot firer; the miners, with few exceptions, not being permitted to fire their own shots. They are required to lay their own road bed, and to keep their place timbered clear to the face, with sets every two feet.

The Vale coal is very hard and tightly set, with practically no parting. In this case the cut is generally in the bottom. The coal requires to be sheared; the holes for the most part being drilled directly in the solid. (See Fig. 5.)

In stone drift or tunneling work, compressed air drills are used. The working face is sheared, either horizontally or vertically, according to the nature of the place, and formation of rock, and holes are then drilled all around the shear.

All the coal in the Albion Colliery, in fact in all the mines of the Acadia Coal Company, is mined by hand pick and hand drills. A few punchers or undercutters driven by compressed air are in

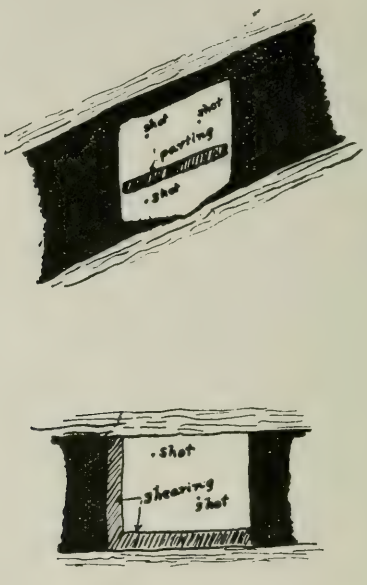

FIG. 5.
The Working Face.

use at the Allan shafts, and percussion air driven drills are used at all the collieries, but only in shaft sinking and in driving stone drifts.

Wages.—The following is a scale of miners' wages:—

For driving balances	85c.	per ton.	
" driving bords	61c.	"	
" drawing pillars	55c.	"	
" driving levels	78c.	"	(double shift).
" " "	73c.	"	(single shift).

For driving heads (between levels), $1.00 per yard over and above tonnage. The miner driving a level is also required to drive these heads, and as they are solely for the purpose of forming an air circuit, they are only about four feet high, hence the price paid.

Two men usually work at a face; they are charged with the powder they use and engage their own loader, whose minimum wage is $1.48 per shift. The average wage of the loader is about $1.80.

The men who drove the stone drifts from the Cage to the Longwall seams were paid $3.50 per lineal yard.

Gas.—The seams are noted for the amount of gas given off, and the large quantity of dust that is made. Rigid precautions are taken to ensure the safety of the workmen. Wolff safety lamps are used, but as they are pronounced dangerous if the relighting device is utilised in gaseous places, the men are prohibited from relighting their lamps at the face, and are required to carry their lamps to be relit to the relighting stations, of which there are a number conveniently placed, and where the air is pure.

Haulage Underground.—The two levels running east and west from the bottom landing of the Third seam slope form the main haulage ways of the mine; all the coal from the Ford, Cage and Third seams being handled on these levels and then hoisted up the main slope. The coal from the working faces, balances, etc., is hauled out to the main landing by horses.

The usual style of hoisting engines are used on the Third and Deep Seam sinkings. These engines, however, being underground, are driven by compressed air, and are set a short distance back of the level at the head of the sinking, the ropes being under the level tracks.

Tracks and Track Laying.—There is a material difference in the construction of the roads on the main haulage levels and those leading into the rooms; the former being subject to harder and more constant use, require that they shall be more firmly and substantially constructed. The sleepers are placed about three feet apart; the roads are well ballasted with refuse material and fine coal, which in course of time becomes very compact and makes a good bed. At places, where the road bed is for temporary purposes only, and likely to be taken up at short notice, a special 4 foot rail is used. These rails have no flanges, and are merely placed in grooves cut in the sleepers. A large supply of these sleepers and rails is always kept on hand. At turnouts and landings, where the traffic is heavy and constant, the tracks are generally laid on 2-inch planking, closely packed. In the sinkings

the sleepers are let into the rib on each side, to prevent the road bed from slipping down the pitch. The tracks on the main slope are laid on sills 6 inches by 4 inches. The guage on the underground road is 2 feet 2 inches.

To carry the rope and to lessen friction, wooden rollers are placed at regular intervals on the sinkings and slopes. These rollers are of simple construction, being pieces of common hardwood rounded on the lathe and having a groove cut in them for the rope to fit in, and an iron axle passing through the centre. These are placed midway between the rails in wooden frames equipped with iron bearings in which the axle turns.

Timbering.—The timbering consists, to a great extent, of ordinary sets—two props or trees and a cross boom. In certain parts of the mine centre props have also to be used. When timbering the slopes, balances, levels, etc., the trees are placed at right angles to the pitch of the seam and usually about two feet

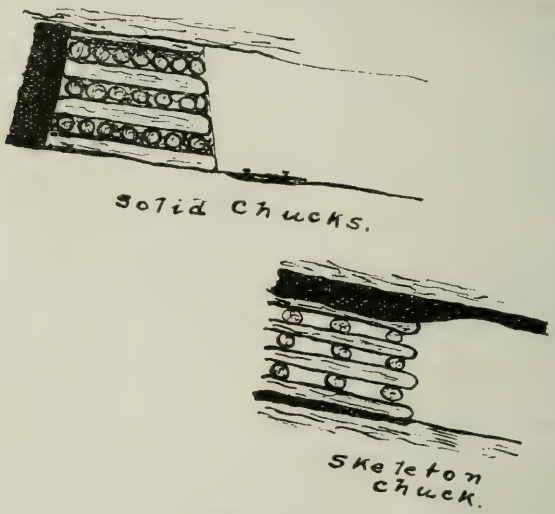

FIG. 6.
Methods of Timbering.

apart. A boom is erected, held first in place by a temporary centre prop, or "Samson;" then the trees are placed under the booms at both ends, and wedges placed wherever practicable

between the boom and roof. The waste formed by mining operations, stone, etc., is used in packing the ribs. Slabs and old props are placed behind the trees, the space between the slabs and ribs being then filled in with the mining waste. If this were not done, the rib would be continually breaking away.

In a great many places the roof becomes exceptionally heavy, requiring the use of chucks. These are built of trees and booms and are of three kinds, i.e., solid, skeleton and block. In the solid chucks the booms are placed closely together and built up

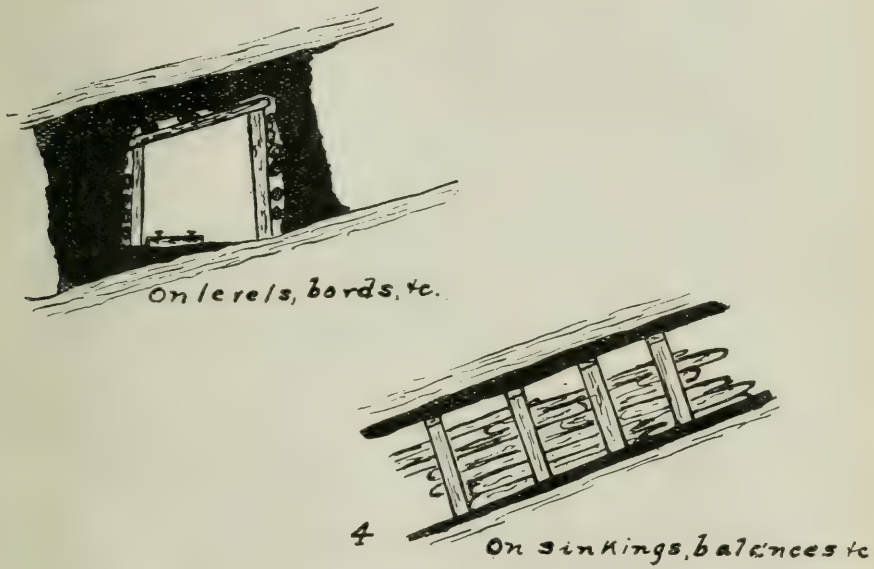

Fig. 6.

in layers, each layer being placed in the opposite direction to the one beneath. They are from 10 to 12 feet wide, and extend to solid coal in high and low side ribs and roof. The whole chuck is then tightly wedged and covered with mortar, and thus affords a good protection against fire.

The skeleton chucks are generally used to support heavy roof, and are built up in the same way as the solid chuck, but the trees or booms are placed some 18 to 20 inches apart. The greater the pressure of the roof on these chucks the tighter and more solid they become.

In the block chucks the booms are placed close together, as in the solid chuck, but the layers all run in the one direction. (See Fig. 6.)

An instance of the enormous pressure on the roof in deep workings was observed by the writer in the Acadia mine. Here a solid chuck, built originally 5 feet high, was squeezed down to 6 inches.

VENTILATION.

The mine is well ventilated. The general scheme may be set forth as follows:—

The Third seam fan and fan engine, made by Walker Bros., Wigan, England, were installed about 15 years ago. The engine is a compound, developing, at the regular rate of running, 145 h.p. The diameter of its cylinders is 16 inches; length of stroke, 3 feet; number of revolutions, per minute 50.

The large driving wheel of the engine, 16 feet in diameter, is connected by six large ropes (running in separate grooves on the driving wheel) to the speed pulley, 6 feet in diameter, which is connected directly to the fan shaft. The fan, which, of course, is directly over the fan pit, is 19 feet in diameter; width of blades, 5 feet. It makes 120 revolutions per minute (or nearly three times as many as the engine), and sends 60,000 cubic feet of air per minute into the mine, the water guage standing at 4 inches.

Third Seam, West Side.—The air enters by the main slope and splits at bottom landing east and west. The air on the west side, after circulating through all the rise workings, returns up the old No. 1 slope to within 150 feet of the surface. Here a cross cut was driven towards No. 2 slope, a staple pit or shaft sunk and a drift driven under this slope, and by means of another shaft, connection made with the east side return airway and so to the fan pit.

East Side.—On the east side the air circulates through the sinking and rise workings, etc., and returns up the main travelling road. Near the surface the road divides, one goes to the fan pit, the other through double doors to the surface. (Fig. 7.)

Cage or Deep Seam, West Side.—The air enters the Cage seam by way of the stone drift from the 1,700 foot level of the Third seam slope; splits east and west, circulating through all the work-

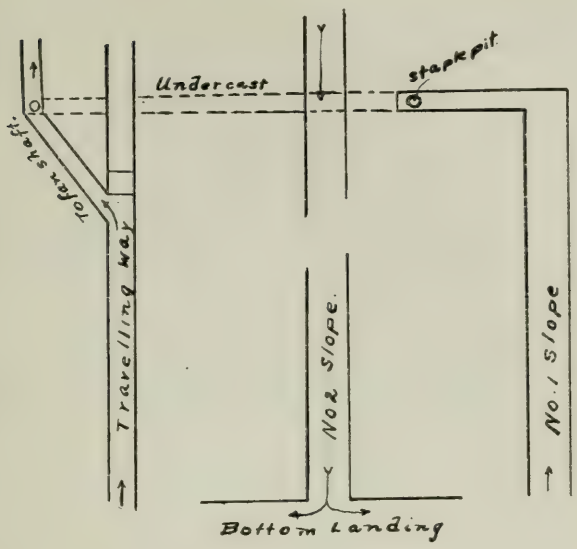

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FIG. 7.
Return Air-Way, Third Seam

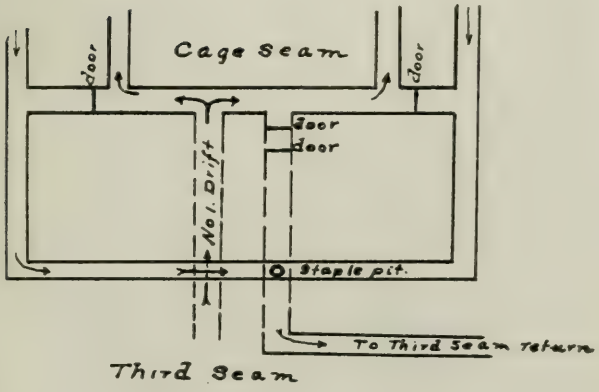


FIG. 8.
Return Air-Way, Cage Seam.

ings, sinking, etc., and returning again to the rise workings. Referring to sketch: the top bord was driven over to the second drift, and a staple pit 20 feet deep was sunk. The air passes down the staple pit, thence through the cross-cut to the return airway, east side, Third seam.

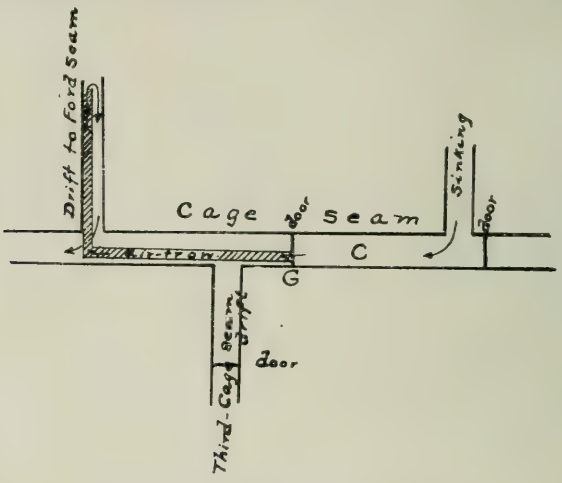


FIG. 8.
Plan of Ventilating, Face in Ford Seam.

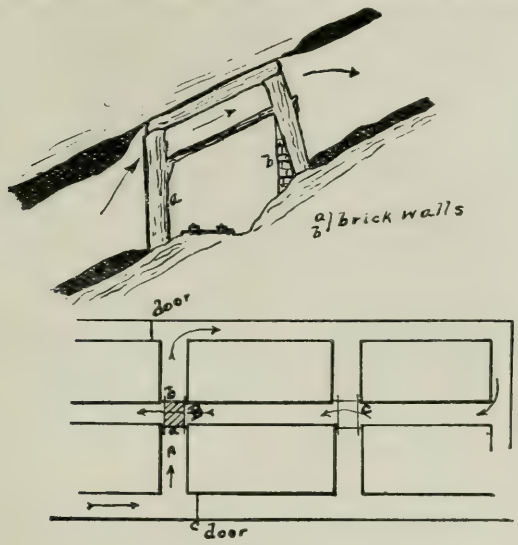
East.—Precisely the same method as described above pertains to the return on this side.

Ford or Main Seam.—(Fig. 9). The air from the Deep seam workings returns along level "C." A large wooden trap door is at "G," and an air trow was built and extended to the entrance of the Ford seam drift. This drift is divided in two by a line of bratticing, the air entering through one half and returning on the other half, circulates through the rise workings of the Deep seam, and returns as described in the previous paragraph.

Trap Doors, Trows, Over and Under Casts, etc.—Where necessary, the air is guided through the workings by the use of wooden doors, canvas doors, over and under casts, air trows and brattice work, as explained below.

While heads are being driven from level to counter-level, air must be sent to the working face, and air trows are generally used for this purpose. These trows are made from $\frac{3}{4}$-inch brattice

boards and are 20 inches square inside measurement, and from 10 to 15 feet in length. The joints are all battened, covered with canvas, and thus made as nearly airtight as possible. One



Overcasts.

great advantage in using trows is that, being comparatively light, they can be moved from one part of the mine to another. The trow used for ventilating the Ford seam, as described above, is, of course, considerably larger than the average.

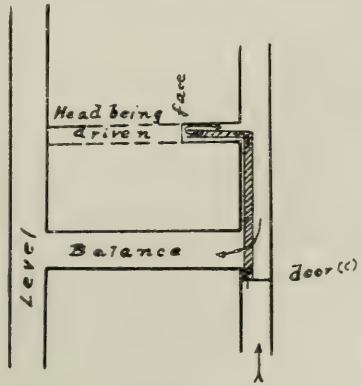


FIG 10.
Use of air trows.

The more general use of trows and over and under casts can be better understood from sketches Fig. 10.

Over and Under Casts.—Suppose it is required for the air to circulate as indicated by the arrows: at *a* and *b* brick walls are built, and then a wooden box or frame is built on top, ends at *a* and *b* being open. The whole is carefully mortared and fitted close to the ribs and roof. At *c* is a door; the air must pass up *A* through the over-cast; circulates as arrows indicate, through another over-cast at *C*, along the bord and under the over-cast *B*.

An example of an under-cast is sketched as No. 5, where the west side return air, Third seam, is made to pass under the Third seam slope.

Drainage—The water from all the seams—Ford, Deep, Third and McGregor—is pumped to the surface from the base of the McGregor slope by a large triple expansion condensing pump, which exhausts into a condenser, so that there is practically no steam in the mine. The pump has 10 inch plungers, the length of stroke is 3 feet; the average number of strokes per minute, 28–30; about 40 gallons of water are pumped at each stroke. Intake and delivery pipes are both 10 inches inside diameter. The steam pipe is 8 inches inside diameter, to within 60 feet of the pumps, then a 6 inch pipe is used. From 10 to 15 pounds of steam is lost through condensation. This water is run out by means of automatic traps placed at regular intervals along the pipe.

There is a drift from the Ford to the Cage seam at "F," as shown on plate III. Many men escaped by way of this drift at the time of the Ford pit explosion, 1881. The Ford pit water rises to a certain height here and is then carried along a pipe to and down the staple pit to the top of the Third seam sinking, where a small reservoir was built.

The drainage from the Deep and Third seams is also run into this reservoir. From here a bore-hole was sunk to the McGregor seam which came through on No. 6 lift, and from thence the water is conveyed through a 4 inch pipe down the slope to the pump. A second bore-hole was sunk to the McGregor from the bottom of the Third seams, sinking in order to get rid of the sinking water.

Conclusion.

The general principle for mining the coal is practically the same at all the mines; yet no two mines are worked exactly alike, some modification having to be made for ridges, dips, etc. Although this report is descriptive of the working of one mine only, nevertheless its heading, "Coal Mining in Pictou County," seems justifiable.

The references to geology and historical facts are extracts from "The Pictou County Coalfield," by Mr. H. S. Poole, and from several articles by Mr. H. E. Coll appearing in the *Engineering and Mining Journal.*

The writer desires to thank Mr. Charles J. Coll, general manager of the Acadia Coal Co., for his assistance, and Mr. Angus McKay, underground manager at the Albion colliery, for information and costs.

NOTES ON THE KING BROS.' ASBESTOS MINE, THETFORD, QUEBEC.*

By EZRA B. RIDER, McGill University, Montreal.

To the south of the river St. Lawrence, in that part of Quebec province known as the Eastern Townships, and 115 miles distant from Montreal in a direct line, is situated, the greatest asbestos area in the world so far as present known. One of the largest and most profitably worked mines in this area is that of the King Bros. Company, located on lot 26, ranges V and VI of the township of Thetford. Part of the town is built on lot 26 on land owned by the King Bros. Company, and is leased to house owners on conditions which, it is believed, permit the Company to move the buildings at any time, should mining purposes require.

Thetford, with a population of 7,000, is on the main line of the Quebec Central railway, 76 miles from Levis, 67 miles from Sherbrooke, 175 miles by rail from Montreal, and 473 miles from New York, with which last-named city it has direct rail connection by the Quebec Central, Boston & Maine, and New York, New Haven & Hartford railroads.

TOPOGRAPHY.

The surrounding country is rugged; the hills, however, rise to no great height, their most extreme altitude being about 800 feet above the general land level. Formerly this whole area was heavily wooded, but lumbering operations and forest fires have removed the greater part of the heavy timber, so that now second

The writer desires to record his indebtedness to Mr. W. J. Woolsey, of the King Bros. Company, who was good enough to supply certain information incorporated in this paper; and to Mr. B. Bennett, the Mine Superintendent, for permission to examine the property. The writer has also consulted the monograph on "Asbestos," published by the Mines Branch of the Department of Mines.

*Student paper entered for 1909 Competition and awarded honourable mention.

growths form the wooded districts. In many parts of the country agriculture is carried on, but the areas of good farming land are not extensive.

The rock surfaces of the hills are covered by a mere film of soil, a condition favorable to both prospecting and mining. But this is not the case on the lower slopes, where the layers of soil, largely composed of glacial drift, are from a few feet to twenty feet or more deep. In many places where the soil has been removed the uncovered rock presents smoothly polished and striated surfaces. In one instance, in serpentine, the grooves were nearly one foot broad, shallow but quite distinct.

A small river flows through the town, affording sufficient power for lighting requirements. Steam power or electric power, transmitted from a distance, is used by the mines, the King Bros.' mine being operated by electricity generated at Shawinigan. The small river referred to is the only dependable source of water supply within a radius of several miles of Thetford.

Geology.

These Quebec serpentines in which the asbestos has been found belong to one of the many areas of similar rocks, which may be described as forming a belt extending from Georgia to Gaspé. The Thetford area forms part of a series of elevations known as the Notre Dame mountains, an extension into Quebec of the Green mountains of Vermont.

The formation is referred to the Cambrian. Intrusive igneous rocks, rich in olivine and chromic iron, have been metamorphosed to serpentine. Further change of serpentine to asbestos has taken place. Advanced regional metamorphism from the original rock type is apparently essential to the development of the superior fibres, and the presence of dike intrusions has apparently influenced the metamorphism. This is especially the case with the acidic dikes which are believed by many to have played an important part in the development of the chrysotile, by causing shrinkage in the rock, thus forming fissures in which fibres can crystallize. The serpentine is much fractured. This is due not to any system of faulting, but to the effects of expansion, attributable to the increase in volume of the metamorphosed rock.

Asbestos veins are irregular, both in respect of size and distribution in the serpentine. The question of depth does not appear to have any appreciable effect on either the quantity or quality of the mineral, though certain portions of the serpentine are much richer.

Analyses of serpentine and chrysotile show practically the same composition, any variation being in the amount of impurities which would be held in the massive rock. A sample of Thetford fibre, analysed by Dr. J. T. Donald, afforded the following result:

Silica	39.05%
Magnesia	40. 7%
Ferrous Oxide	2.41%
Alumina	3.67%
Water	14.48%
	99.68

So far nothing conclusive has been advanced to explain the manner in which the asbestos fibres have been developed. Mr. G. P. Merrill holds that the fissures are due to shrinkage, and that in them crystallization took place from the walls inward. Mr. W. J. Woolsey, however, has come to the conclusion, after microscopically examining certain thin sections, that crystallization proceeded from a central fracture outward.

The importance of the industry would seem to warrant a more exhaustive study of the formation of veins of chrysotile in serpentine rock.* Asbestos of good quality was discovered prior to the year 1862 near St. Joseph, Beauce county, distant about 30 miles from Thetford. The deposits were limited, and attempts to work them at a profit failed. In 1877 another discovery was made of fibre in the serpentine hills at Thetford and Coleraine. The following year saw mining operations prosecuted on a small scale, with a production of about 50 tons of excellent quality fibre.

* The Canadian Geological Survey has now in press a report on this region by Mr. J. A. Dresser. It is believed much valuable information will be contained in this report in respect of the points here raised.

Historical Notes and Statistics.

Work was first prosecuted on the King Bros.' mine in 1879. For a number of years mining was conducted on a crude and small way, the production of all the mines in 1889 being only 9,000 tons.

A condition of general business depression in Canada and the United States arose, and this industry suffered in common with others. Many mines were closed, and those dealers who had bought and were holding large stocks were obliged to sell at a sacrifice. About the year 1895, however, the demand for asbestos increased, occasioning a more extensive development than at any previous time. The growth of the industry to date is meanwhile clearly indicated by the following statistical table:—

1889	Production	9,000 tons	Value	$1,250,000.00
1899	"	40,000 "	"	1,250,000.00
1907	"	62,000 "	"	2,500,000.00

Studying these returns, it will at once be noted that, although a very considerably increased production was made in 1899, yet the value of the output was no greater than that of the year 1889. This is attributed to the fact that, while the sales in 1889 were almost exclusively of almost pure fibre, commonly called "crude," the production of 1899 was largely of lower grade products, from rock which had formerly gone to the dump, but which, with improved milling methods and increased demand for low grade products, could now be profitably utilised. In the last ten years a large proportion of profits has been derived from the dumps and low grade rock-material formerly rejected.

Early in 1905 the mine, plant and asbestos areas of the King Bros. Company in Thetford and district were acquired by a number of American capitalists associated with Mr. H. M. Whitney, of Boston. During the time of their operation of the property many improvements were made to the plant, looking to cheaper, more efficient and more extensive mining and milling of the asbestos-bearing rock. These ends were attained; but the recent stringency in the United States money market forced the new owners to dispose of the property, which was repurchased by the original owners. Amongst the improvements referred to may be

mentioned the installation of electric power to replace steam, of a larger compressor plant, and of a new mine locomotive and additional cars.

The operation of the King Bros. Asbestos Company forms part only of the more extensive lumber and mining business controlled by the King family, of Quebec city. The mining operations are carried on under the management of Mr. B. Bennett, who has been connected with the industry at this mine for many years. Associated with him is Mr. W. J. Woolsey, the night superintendent, and under them are foremen in charge of small gangs. The surveying of the mine is undertaken at intervals by a surveyor whom the King Bros. Company retain for timber and mineral surveys.

MINING.

Mining operations are carried on, after the open cast method, in a single open pit or quarry. The pit is about 1,000 feet long, 600 feet wide, 180 feet in depth, with the direction of the long axis nearly 45 degrees west of north. The open cast method has certain advantages over underground mining, amongst others being the easy supervision of the work, good ventilation, the saving of timber, and no loss in the form of pillars. There are, however, more serious disadvantages, such as loss of time in stormy weather, increased cost of milling wet rock, and greater pumping expense, particularly in freeing the pit from water resulting from the melting of the winter's ice and snow.

In the Bell Asbestos Company's property, underground working has been in progress for some time past. The method is to drive an incline at about 20 degrees, so as to strike the bottom of the pit. From this incline, at convenient depths, drifts are run at right angles, and from these branches are driven as required. The objection to this method is the greater cost of mining it entails, while the value of fibre is decreased as a consequence of blasting in a confined space. The advantages are: far greater efficiency of labour in the winter season, hoisting of the material from one central point instead of by many different cables, and the saving made in the milling process by eliminating the necessity of drying the rock.

Underground work was attempted in the King Bros.' pit, but the drift was abandoned after being carried in about 60 feet.

1. General view of King Bros.' Mill and other buildings.
2. Type of cable support in use at Bell Asbestos Co's Mine.

This drift is shown in photo No. 2. No. 3 also shows a small drift, which was run only a few feet. These photographs show views of the pit as seen from each end.

The serpentine contains cracks and slips of considerable extent, but is apparently sufficiently solid to enable drifting to be carried on successfully, without expensive timbering. The failure of the attempt to introduce the method seems to have been due in large measure to apprehension on the part of the men, the majority of whom may be described as "farmer-miners," since many were formerly farm hands. For open cut work they are most efficient, but are unaccustomed to underground mining, and are extremely timorous. When serpentine is blasted it shatters somewhat, and this broken rock in a drift requires to be taken down; but with the exercise of proper care there seems no reason why regular underground mining methods could not be followed. In a case where the greater part of the material may be cobbed and milled the opportunity would appear to be excellent for the operation of the mine by a modified pillar and stope system, similar to that in use at the Granby mine at Phœnix, B.C., for by the employment of this method much shovelling consequent upon the direct loading of the rock into cars from the chutes would be saved. So soon as the stopes had become as large as it were possible to work them, in the summer season they could be broken through and mined into the same chutes. There would also be a great saving of time, for in open pit work operations are seriously impeded by rain in summer and by snow and cold in winter. It is usual in the winter season to shovel the snow back from the rock face as the work proceeds. This entails a great deal of useless labour, besides hindering mining operations. Further, it is so cold in the pit on a winter day that work is only prosecuted under serious difficulties.

On the other hand, it may be granted that the adoption of the pillar and stope system would result in a considerable loss of "crude" in the shutes, which at present is gathered up by the hand pickers, but this loss would not offset the gain.

Again, when the company decides to prosecute underground work, and employs miners accustomed to regular mining methods, the chances of accidents will probably be less than those under the present system. Thus, one of the serious dangers of the

present system is that of men being struck and thrown over the edge of the pit by the boxes travelling back and forth from pit to cars; in fact, several fatalities have resulted here from this cause.

The mine is drained by a single reciprocating steam engine, pumping from the sump and placed near the north-west end, at the lowest part of the pit. The pump is protected by timbers from falling rocks and blasts.

Ventilation presents no difficulty at present, as the men are always working in the open air.

The pit is effectively illuminated at night by three search-lights, two being placed at the south-west and one at the north-west extremity. Each station is in charge of a man who turns the light where required, while one light is trained on the cables, thus enabling the hoistmen to watch the carriers.

When commencing mining here the first operation is the removal of the drift, which, as shown in the photograph, has, at the edge of the King Bros.' pit, a considerable depth, in some places being over 15 feet thick.

The stripping was formerly done by pick and shovel, earth and stones being loaded into cars and hauled to the dump; but a small Marion steam shovel, model 20, loading directly into cars, is now employed for this purpose. The edges of the pit are advanced very slowly. Beginning at the surface the wall is broken down in steps towards the bottom, but practically all the work at present is confined to the pit bottom and lower side stopes or shelves.

On day shift upwards of 120 men are employed in the pit, while five two-men drills and a number of Murphy hammer drills for blockholing large rocks are used. A considerable force of men is employed in breaking rocks with hammers, and at first sight this appears to be a very slow and expensive method. The rock, however, breaks comparatively easily under the blow of an experienced hammerman; then good fibres are exposed, and the men work steadily, and are not paid very high wages. Under these conditions, therefore, it is cheaper to break by hand than to blockhole and use powder for breaking the smaller pieces. Other men with picks and bars pry out broken rock after blasting; others with pick and shovel load the pit stuff into the hoisting

Cable Derricks, King Bros.' Mine.
King Bros.' Pit looking North-West. King Bros.' Pit looking South-East.

boxes; while again others gather up in hand boxes asbestos broken loose from the rock, or cob rock for good fibres. This material does not go to the mill, but after further cobbing and sifting, is marketed as No. 1 Crude, and is worth from $250 to $300 per ton. With the low cost of labour now obtaining, of $1.75 per 10-hour shift, and the high value of the crude, it is profitable to handle large quantities of rock with a view to picking out the good fibres, which, if sent direct to the mill, would depreciate in value as a marketable product.

The rock walls are taken down in steps having approximately vertical faces.

Machinery and Equipment.

The majority of the drills used are No. 3 and No. 3¼ Rand, of 3⅛ inch cylinder and a stroke of 6¾ inches. Each drill is in charge of a runner and his assistant. The machines are driven by compressed air, conducted through heavily wound rubber hose from large mains at the pit edge. Many of the drillers are inexperienced men, and consequently do not get the best possible results from the machines; an average in serpentine of from 40 to 45 feet per 10-hour shift is, however, attained, the holes being from 6 to 10 feet deep, and for very high faces, 15 feet or more. The drills are equipped with blowers consisting of a long metal tube attached to a rubber hose, which is connected with the air pipe near the drill. With this the holes are blown frequently, and the arrangement works more satisfactorily than wet holes in the open air, where the dust is carried away by the wind.

Hammer drills are used for blockholing large rocks which have been broken down from the faces. No sand blasting is done. The chief objection to sand blasting is that it breaks the rock too finely and scatters it too far, so that much fibre which would make good "crude" is thus put through the mill with the pit fines. A light blasting charge is employed for blockholes, the weight of the charge being just sufficient to crack the rock apart and enable the cobbers to gather up the loosened fibres.

The explosive employed is 40%. For deep holes the usual practice is to charge about .5 lbs. per foot. In blockholes from one quarter to one half of the ordinary stick is required, depend-

ing, of course, on the size of the rock to be broken. The blasting, which is in charge of firemen, is done at noon and at night.

All hoisting is done by means of cable derricks, of which there are twelve. The carrier ropes, which are about 1½ inches in diameter, are made of crucible steel, and are stretched nearly horizontally across the pit from anchorages near the hoist houses over supports (as shown in photo No. 3), and thence to anchorages across the pit. The anchorages are either heavy iron bars set in holes in the solid rock, or deadmen, that is, large wooden blocks weighted down with stones. To take up the slack when necessary turn buckles are inserted in the carrier ropes near the anchorages.

The cable derricks at the King Bros.' mine are all of the two-leg type guyed by two wires, the carrier rope acting as a third guy. They are preferred to the four-legged tower, since they are easier to move and are quite sufficiently steady. Photo No. 4 shows a tower of the four-leg type at another mine.

The hoist chiefly in use is the special cableway hoist manufactured by the Jenckes Machine Company, of Sherbrooke, and has friction drums mounted on one axle, with brakes worked by hand lever, and is driven by a duplex link motion engine. This hoist is simple in construction, cheaper than those with separate drums, and is replacing them for horizontal cableways. Four of the hoists are operated by steam, and eight by compressed air. Steam for the four hoists is supplied from a small boiler plant located near them, which also provides steam for the mine pump. This plant consists of two Jenckes Machine Co. boilers, working at 80 pounds pressure, and having a total capacity of 150 h.p.

The compressor plant which supplies the other hoists and the drills is also situated near the pit. The compressor is a new 40-drill Rand, rope drives from a 30-cycle synchronous motor, 602 h.p., 2,200 volts, 118 amperes, making 450 revolutions per minute. The air goes first to storage tanks, thence to the mains.

Besides lifting material from the pit, the cables are used for shifting heavy pieces of rock away from the working face after blasting, so that the hoists seldom produce rock to their full lifting capacity, which is about 250 tons per shift of 10 hours.

The average number of boxes lifted from the pit per hour, each holding nearly a ton, is about 80; hence about 800 tons of rock is hoisted during the day shift. During the night shift about 200 tons is hoisted.

The hoist men are signalled from the pit by boys stationed along the pit edge, to whom the pit men shout or make signs, the boys in turn communicating with the hoist men by means of electric bells.

The hoisting boxes, which are of about one ton capacity each, are made of 2-inch hardwood provided with sheet iron protected bottoms. These boxes are dumped into cars standing on the tracks built along the edge of the quarry. The box is lowered to rest in the car, the lifting chain is unloosed from the front edge, and when the box is lifted its load spills into the car.

The cars are built at the mine shops and are used not only to transport material to the mills, and waste and sand to the dumps, but also serve in place of storage bins. There are in all two hundred of them in use; hence a full day's output from the pit may be stored in them if necessary.

The cars are handled by three locomotives, one of the regular light type of mine locomotive, the others of special construction, built at the mine after the design introduced in 1895 by Mr. George R. Smith.

Mining Practice.

When mining, no pillars are left in the pit, all rock material, even that of the dykes and the lean serpentine being removed. The dyke rock and sand from the mill go to one dump, the lean serpentine to another, where, if a profitable method of treatment be discovered, it may be readily handled. The dumps are placed in the north-eastern end of the property, on the far side of the Quebec Central railway track.

As already mentioned, the output of the mine is about 1,000 tons per 24 hours. The portion requiring concentration is treated in two mills, one of which is in continuous operation and treats 300 tons daily, the remainder being treated in a new mill, which is operated one shift of ten hours.

General.

Of the total rock mined, over 60% is milling material, which after treatment yields three products—No. 1, No. 2, and No. 3 fibre. In addition, two crude products are obtained from hand

cobbing in the pit and at the crushers. The proportion of each product in the total output of asbestos is about as follows:—

No. 1 Crude	4%	$250–$300 per ton.
No. 2 Crude	6%	$120–$150 "
No. 1 Fibre	20%	$45– $70 "
No. 2 & 3 Fibre	70%	$18– $40 "

The prices given are per short ton at the mine.

The total number of men employed in the pit, mill, and on the surface, is about 400. Two shifts are worked per 24 hours, with a light gang on night shift. During the five summer months the men work a ten and a half hour day for five days in the week, namely, from 6 to 11 a.m., and from 12 to 5.30 p.m. In addition to their wages the Company insures its employees against sickness, accident or death. The miners' wages are as follows:—

Foremen	$2.00 per shift.
Drillmen	$1.90 and $2.00 " "
Drill helpers	$1.75 " "
Ordinary laborers	$1.75 " "
Boys signalling for one derrick	60 " "
Boy signalling for two derricks	$1.00 " "

MILLING.

The No. 1 and No. 2 crude are entirely hand treated, in order that the pulverizing effect of the milling may not decrease their value. The crude which is gathered up in the mine is taken to the cobbing sheds, where men, boys or girls cob the veins carefully, rub them over screens to remove impurities, and bag for market.

The pit fines and crusher rock go through a process consisting of crushing, drying, finer crushing, cyclone pulverization and screening. Air suction is used at all convenient stages to remove the fibres as they are reduced, thus drawing them away to prevent their deterioration in value by further milling. The material is is passed through Blake crushers breaking to three inches. Drying is done by means of revolving cylindrical tubes about 30 feet in length and three feet in diameter, and having an inclination of about ten degrees. These are enclosed in brickwork to reduce the loss of heat as much as possible, and are fired externally, the hot gases passing along the shell and up a stack at the end. The

broken material, fed in at the upper end, is mechanically stirred by blades in its passage to the discharging end, to give the warm air free access to it.

Much heat is lost by this method of drying, and since in winter and rainy seasons the expense of drying counts a large part of the cost of production, improvements are being considered. In fact, a Wood's producer gas plant has just been installed in the old mill with the object of burning gas inside instead of outside the cylinder. Even so, there is bound to be a great loss of heat, or unused heat, unless the arrangement of the cylinders is changed.

The system of underground mining referred to would materially reduce this item of expense.

From the dryer the material passes through crushers, which reduce it to about 1½ inches, whence it goes to the cyclones. These consist of cylindrical or rectangular iron shells, 2½ feet internal measurement, and 4 to 5 feet high. In opposite directions in the lower portions two propeller-shaped blades, weighing about 150 lbs. each, revolve at a speed of from 1,600 to 2,300 revolutions per minute. The reducing action is carried on in the presence of an air suction of from 12 to 34 oz., removing the fibres as reduced, and minimising the deteriorating influence on the quality of the material and consequent loss in value, which is one of the serious objections to this machine. The capacity of a cyclone is from 25 to 50 tons per ten hour shift, depending on hardness and toughness of the rock, the average size charged, and the fineness of the product desired. The product from this machine, together with the fibre obtained by air suction at previous stages in the process, is passed over screens in order to remove all possible impurities. At the lower end of all screens also, air suction is used to draw away fibres to the dusting chambers, where various forms of apparatus are employed to remove the adhering dust, the principle being that of vibration in a current of air. The various grades are carried by conveyors to separate bins, where they are bagged ready for removal to the storehouses, ready for marketing.

NOTES ON THE COPPER LAKE MINE, ANTIGONISH, N.S.*

By JOHN W. MCLEOD, McGill University, Montreal.

The property of the Lake Copper Mining Co., Limited, is historic ground, but it is a difficult matter to distinguish between legend and facts. The occurrence of copper in this region has been long known, the finding of rich boulders leading to intermittent prospecting. So far as the writer could learn from old residents, over sixty years ago, a Cornish miner, attracted by the similarity of the country to his native Cornwall, was the first to begin operations. He drove a tunnel into the side of the hill, marked "old tunnel" on Map No. 1, and it is said made a very rich find. He immediately took ship for England to organize a company to develop the property, but the vessel in which he sailed was lost in an Atlantic storm.

Authentic history dates from 1864 when Dr. Honeyman made a survey of the district and prepared a report for the Government of Nova Scotia. A company was incorporated in 1867 for the purpose of developing the mineralized territory, but, failing to discover a vein, operations were discontinued.

In 1872 Dr. G. M. Dawson, of the Geological Survey of Canada, and Sir William Dawson, of McGill University, visited the Copper Lake district. The former in a letter addressed to Mr. A. P. Ross of Pictou, Nova Scotia, countersigned by Sir William Dawson and dated Oct. 2nd, states:—"I am of the opinion that "the main deposit, which had been giving off such a quantity "of surface fragments, has never yet been discovered, and from "the appearance and size of the boulders, some of which are said "to have yielded from 10 to 13% in analysis, there seems every "indication of a large and valuable deposit of cupriferous pyrites "in the immediate neighbourhood."

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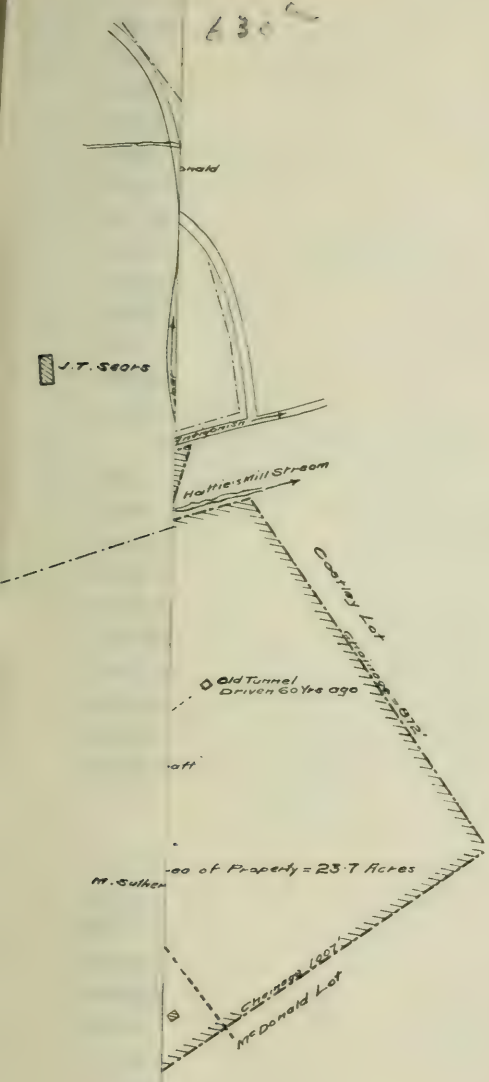
* Student paper, entered for the 1909 Competition.



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PLAN OF PROPERTY
OF
LAKE COPPER MINING CO. LTD.
SHOWING
BUILDINGS AND SOUNDINGS
STRIKE AND DIP OF LODE
COPPER LAKE
ANTIGONISH CO. N.S.

SCALE 1" = 200'

FIG. I.

Mining areas were now acquired by two rival companies, the promoters being Mr. A. P. Ross, mentioned above, and Mr. Alex. McBain of Thorburn, the discoverer of the famous McBain Coal seam. McBain began developments on what is now the surface rights of the Lake Copper Mining Co., Limited, and in 1875 discovered the "Lake Copper Vein." In 1876 the vein was opened by a shaft twenty-five feet deep and, at a distance of 150 feet along the lode, where the superficial deposit is reduced from twenty-five to five feet in thickness, another opening was made; the vein was also located across Copper Lake in Sear's Farm. Unfortunately, the limits of the mining areas of the two rival companies were not properly defined, consequently, McBain's important discovery precipitated a struggle for the possession of the valuable property.

Finally, Ross employed a band of men to drive McBain's men out, and take possession of the mine. For three months Ross' men slept under arms in the shaft-house awaiting the expected return of the McBain forces. On one occasion the sentinel slept and the men within were terrified when they awoke to find that the shafthouse was enveloped in flames. The case was carried into court and appeals were made from court to court, until cost of litigation exhausted the financial resources of both companies. At the expiration of their time limit the Lake Copper Mining Company, Limited, obtained a clear title to the areas of the two rival companies.

Situation.

The property is situated in the south-west corner of the County of Antigonish, Nova Scotia. The mineral rights controlled by the Company comprise an area of ten square miles surrounding Copper Lake, and the surface rights extend over an area slightly exceeding twenty-three acres, situated on the east side of Copper Lake. Map No. 1 shows position and boundaries of surface rights of company.

The property is easily accessible either from Antigonish Station, on the Intercolonial Railway, about 18 miles distant in a northerly direction; or from County Harbour on the Atlantic Coast, in the County of Guysboro, about fifteen miles by road in a southerly direction. Map No. 2 shows the relative position

of the property with respect to the railway systems in Eastern Nova Scotia.

TOPOGRAPHY.

The copper deposit lies almost at the apex, on the northern slope of the watershed, which extends east and west throughout the county. Lochaber Lake lies three miles to the south-west, and South River Lake one and one-half miles to the north-east; the former flowing into the Atlantic Ocean by the St. Mary's River, the latter by the South River into Antigonish Harbour. The country is traversed by a range of low rounded hills, having a general north and south trend, with off-setting ridges, at right-angles. The deposit outcrops on one of the eastern ridges and overlooks Hattie's Mill Stream, which is a short distance to the north of it. This stream has its origin in Copper Lake, and flows eastward into South River Lake. The country immediately surrounding the mine is formed, but in the near vicinity are extensive tracts of forest-land.

GEOLOGY.

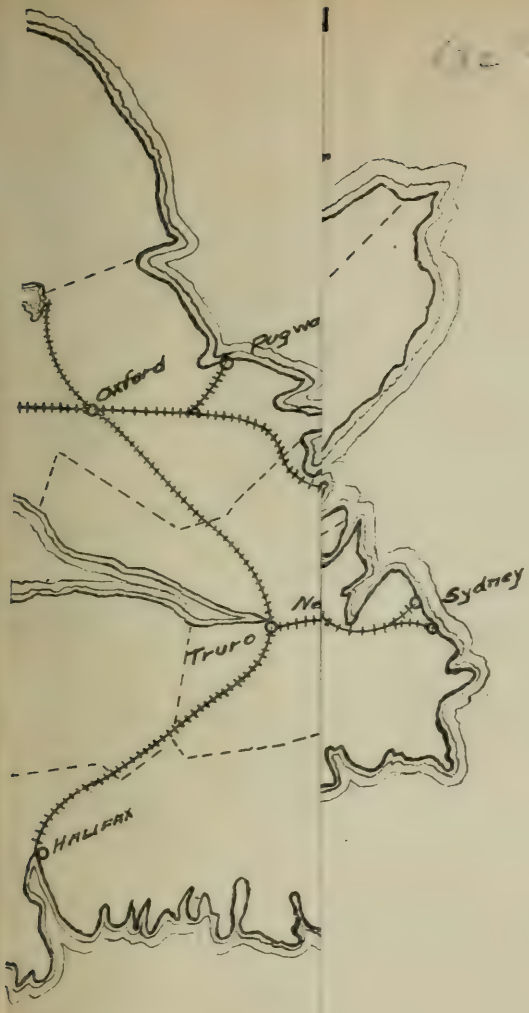
The distribution of the rock formations on the surface of the country surrounding the Copper Lake deposit is shown in the Geological Survey of Canada's Nova Scotia Sheet No. 35, 1893.

The principal openings in the deposit have been made at an elevation of 66 feet above the level of Copper Lake, and 415 feet and 475 feet to the east of it. At these points the ore body is over-laid by about 15 feet of drift.

QUALITY OF THE ORE.

The following assays were made by the firm of Henry Bath & Son, Swansea, England:—

No	Character of Specimen.	Copper.	Sulphur.	Nickel.	Zinc.	Silver
1	Slate or wall rock.....	Nil.	3·60%	Nil.	Trace	Trace
2	Copper ore in quartz.....	9·95%	12·05%	"	"	"
3	Pyrites with little quartz.....	8·78%	44·00%	"	"	"
4	Pyrites.....	Trace	33·51%	Trace	"	"
5	Pyrites and copper.....	17·15%	23·77%	Nil	"	"
6	Pyrites and copper intermixed with quartz.....	9·71%	32·84%	Trace	"	"



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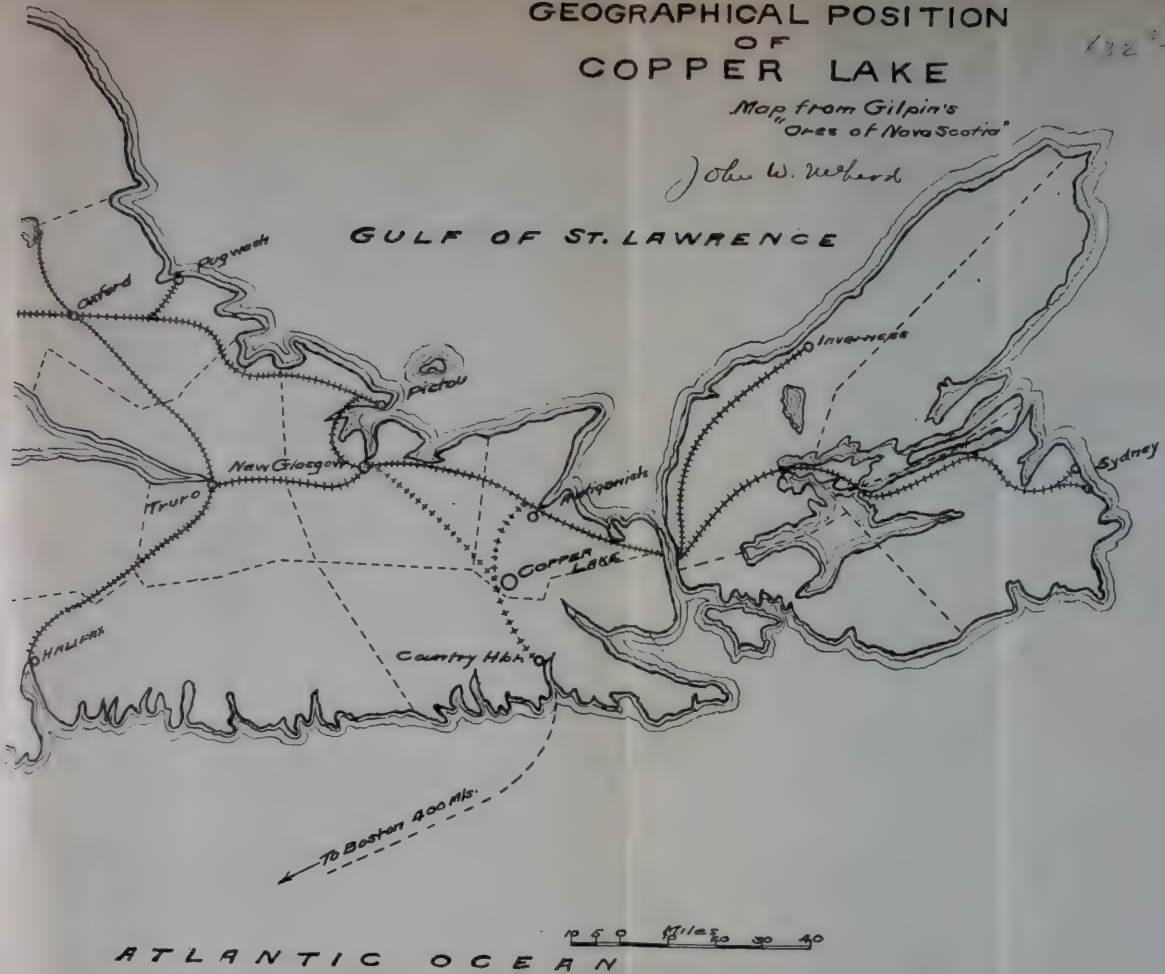
GEOGRAPHICAL POSITION
OF
COPPER LAKE
Map from Gilpin's
"Ores of Nova Scotia"
John W. Webb
GULF OF ST. LAWRENCE
Oxford
Pictou
New Glasgow
Truro
Antigonish
Inverness
Sydney
Copper Lake
HALIFAX
County Hbr.
To Boston 400 Mls.
Miles
ATLANTIC OCEAN

FIG. II.

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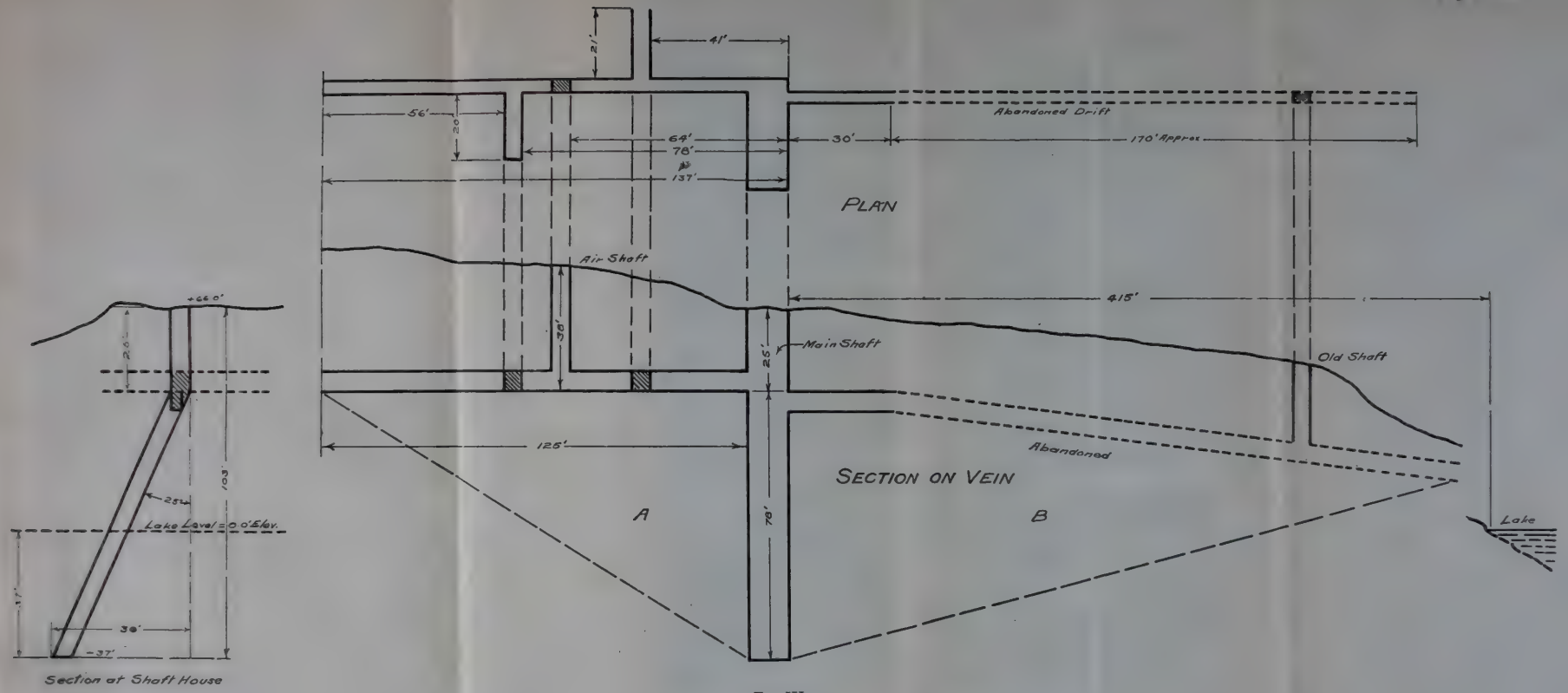

21'
41'
56'
20'
64'
78'
137'
Abandoned Drift
30'
170' Approx
PLAN
Air Shaft
415'
36'
25'
Main Shaft
Old Shaft
125'
Abandoned
SECTION ON VEIN
A
B
78'
Lake
+66.0'
26'
103'
25'
Lake Level = 0.0' Elev.
17'
38'
37'
Section at Shaft House

Fig III.

Page 119, P. Annual Report, 1886, Geological and Natural History Survey of Canada states:—"Two specimens of ore from this mine were examined by Dr. Harrington of McGill University. The first taken from a considerable depth was found to consist of a mixture of copper pyrites, spathic iron ore and a little iron pyrites, containing 11·70% or copper, but no silver. The spathic iron ore is a pale brownish gray in colour, coarsely crystalline, and has a specific gravity of 3·61. It was found to contain 73·68% of carbonate of iron, of 35·573% of metallic iron. The second specimen was from the surface and consisted of copper pyrites, pale iron pyrites, hydrated peroxide of iron and some rock matter. It was found to contain 5·67% of copper."

The following analyses of samples recently taken from different parts of the vein give an average of the distribution of the values:—

Sample taken from.	Copper.	Gold.
East Level	4·66%	0·025 oz.
North Side Shaft	8·66%	0·120 oz.
East of Shaft	7·50%	
West of Shaft	3·30%	
West Level	2·00%	
West Level	0·20%	

Average 4·36% of Copper.

Shipments obtained in course of development were made as follows:—

40 tons	12 —13% Cu.	= 10,000 lbs.	to	Swansea, England.
40 "	11 —12 "	9,000 "		Liverpool, "
27 "	10½— "	5,630 "		New Jersey, "
150 "	3½— "	6,000 "		Pictou, N. S.
100 "	2 — "	4,000 lbs.	on	dump.

Total 357 tons averaging better than 4% copper.

Dr. Gilpin in his Report of June 20th, 1908, to the Commissioner of Public Works and Mines of Nova Scotia, wrote regarding the quality of this ore:—

"At Lochaber there are a large number of mines carrying copper pyrites, and associated with diorite dykes. These veins have been prospected a little and are apparently valuable as the

copper contents in the case of the largest vein, about 6′ thick, were returned for large average samples at 19%. From this point the cupriferous belt has been traced about 4 miles to Copper Lake. Here the presence of large rich boulders instigated a desultory prospecting for a number of years. Finally a vein of spathic ore holding copper pyrites was found in 1875, and traced several hundred feet. Its width as proved by several shallow pits varied from 6 to 11 feet. Large average samples yielded from 5·6 to 11·7 per cent of copper. The distance of this district from a railway and shipping point has apparently postponed development, although it is probably well worth the cost of a railway."

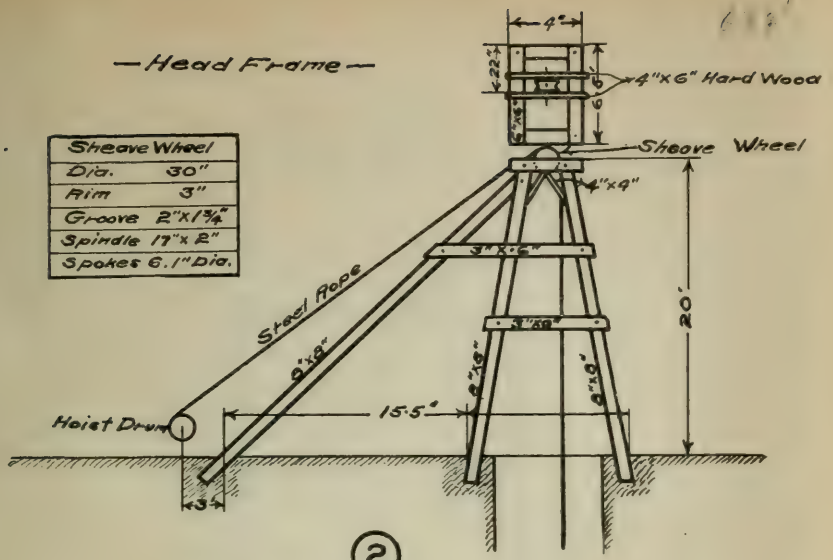
DEVELOPMENT.

The Company is at present confining operations to development in order to ascertain the quantity of ore in the property, proposing to continue the sinking of the main shaft, and at each 110 feet measured on dip to drive levels to divide the ground into approximate rectangles and thus determine the form, size and value of the ore body. The following table will show the extent of development to the beginning of the month of August, 1908.

	Main.	Air.	Aband.	Total Length.
Shaft	103′	38′	25′	166
	East.	West.		
Levels	122	200		322
	North.	South.	South.	
Drifts	30	20	21	71
Total in feet				559

See Mine Map No. 3.

Quantity of Ore.—On the assumption that the vein has an average thickness of 5½ feet, then the triangular body of ore marked "A" (on map No. 3), blocked out by shaft and east level, contains approximately 2,000 tons, and triangle "B," bounded by the west level and shaft, 3,000 tons, or a total of 5,000 tons are now in sight. There is also sufficient data available to esti-


— Head Frame —
Sheave Wheel
Dia. 30"
Rim 3"
Groove 2"x1¾"
Spindle 17"x 2"
Spokes 6.1" Dia.
4"
22½
6
4"x6" Hard Wood
6
6"x6"
Sheave Wheel
4"x9"
3"x6"
3"x8"
Steel Rope
9'-6"
8'-2½"
8'-2½"
20'
Hoist Drum
15'-5"
3'
2

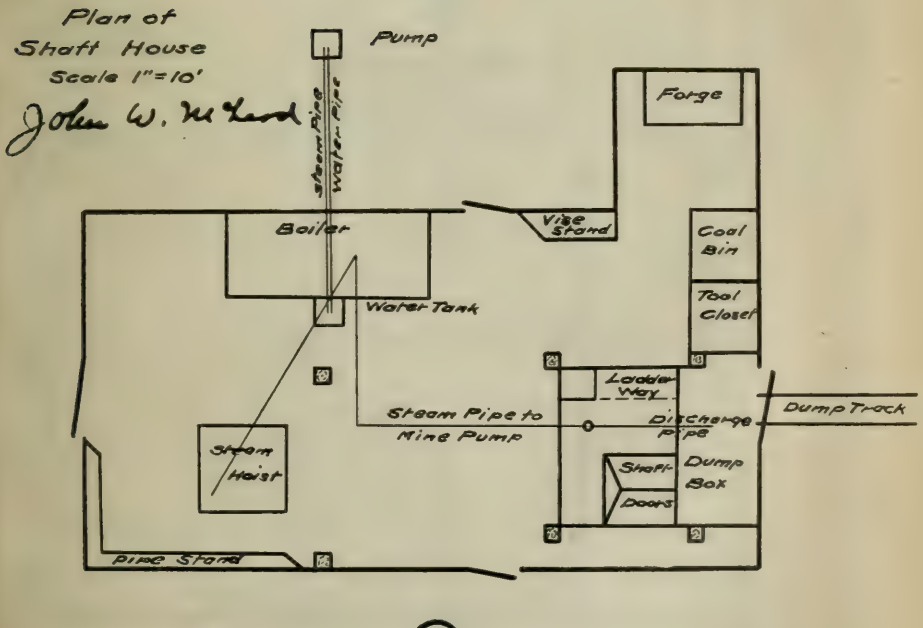
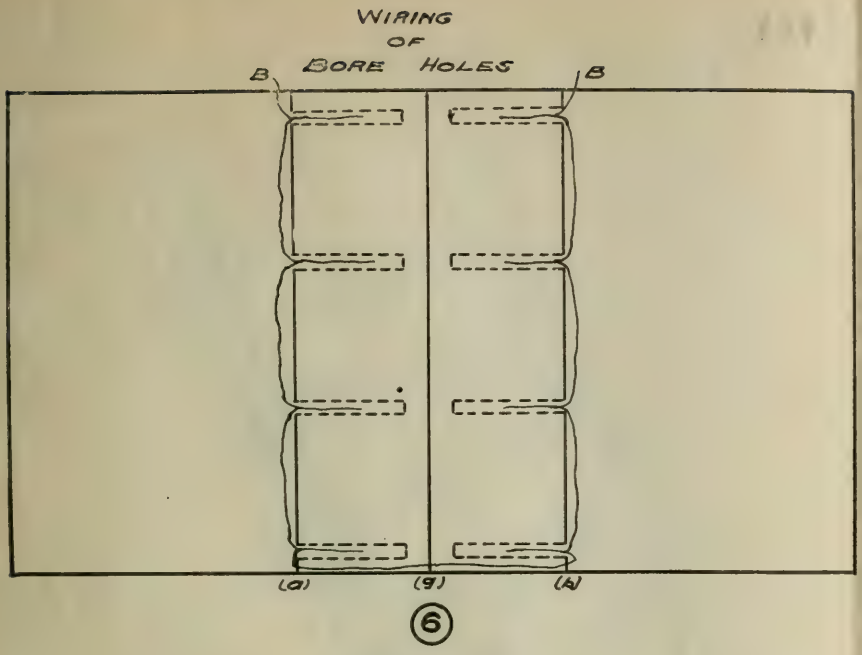

Plan of
Shaft House
Scale 1"=10'
John W. McLeod
Pump
Steam Pipe
Water Pipe
Forge
Boiler
Vise Stand
Coal Bin
Water Tank
Tool Closet
Ladder Way
Steam Pipe to Mine Pump
Discharge Pipe
Dump Track
Steam Hoist
Shaft Doors
Dump Box
Pipe Stand
1

FIG. IV.


WIRING
OF
BORE HOLES
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ARRANGEMENT
OF
BORE HOLES
8'
8·5'
9'
9'
8·5'
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14'
8'
(e)
(c)
(a)
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(b)
(d)
(f)
5

FIG. V.

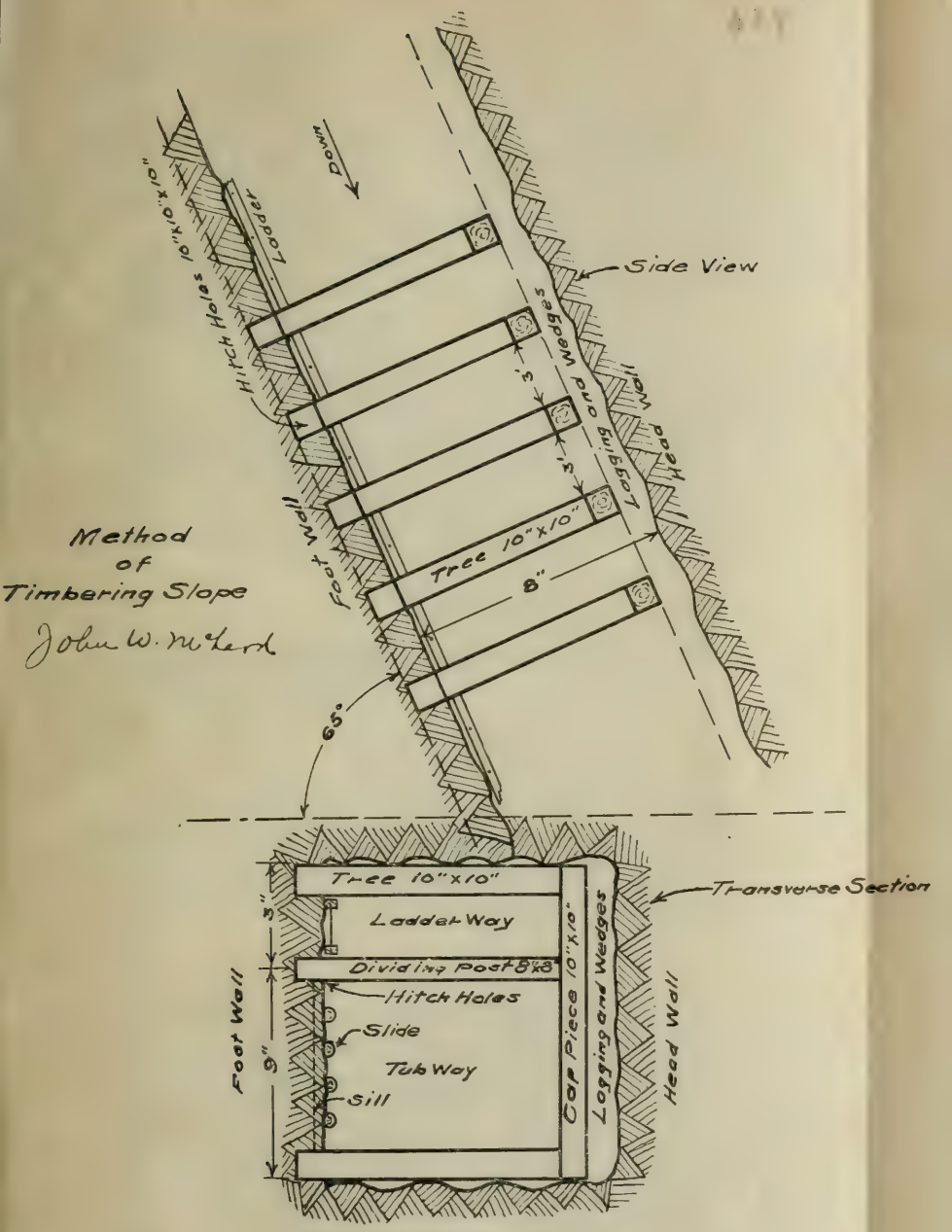
Method
of
Timbering Slope
John W. McLeod
Down
Ladder
Hitch Holes 10"x10"x10"
Foot Wall
Side View
Logging and Wedges
Head Wall
Tree 10"x10"
8"
65°
Transverse Section
Tree 10"x10"
Ladder Way
3"
Dividing Post 8"x8"
Hitch Holes
Slide
Tub Way
Sill
9"
Foot Wall
Cap Piece 10"x10"
Logging and Wedges
Head Wall

FIG. VI.

mate the possibilities of the deposit. From the workings to the point where the deposit has been exposed, at head of the lake, is about 5,000 feet. Now, if we assume, that the ore body holds its strength to a depth of 100 feet, there is here a body of ore measuring 5,000 x 100 = 2,750,000 cubic feet, or about 200,000 tons, almost all of which may be considered available ore.

This apparently over-sanguine expectation was supported by Dr. Selwyn, of the Geological and Natural History Survey of Canada, who wrote as follows regarding the quality and quantity of the lake copper vein:—

"The indications of a very valuable copper lode could not well be more promising than they are in the two pits already sunk in the vein, in addition to which the distribution of the rich specimens, which have been found on the surface and underneath the water of the lake, on the course of the vein, is such as to fully warrant the conclusion that it will be found to hold its character and productiveness for a very considerable distance."

BUILDINGS, ETC.

The mine buildings include a shaft house, cook house, office and blacksmith shop.

MECHANICAL EQUIPMENT.

The machinery equipment comprises a 16 H.P. Monarch boiler, a double cylinder, single friction-drum hoisting engine, a Cameron pump, a Worthington duplex pump, etc.

In addition, an air compressor plant will be shortly installed.

MINING.

Timbering.—The shaft is vertical to a depth of 25 feet, where it follows the dip of the lode, which is about 65°. The method of timbering used through the superficial deposit is locally known as "square set and skin tight." The lowest layer of timber rests on the solid rock, then set lies upon set until the surface is reached. The timber used is hewed hemlock, 8″ x 10″ x 12′, and 8″ x 10″ x 8′ for wall plates and end plates respectively. Corners are framed to resist lateral pressure. For timbering the sloping por-

tion of the shaft hitch holes, 10″ x 10″ x 10″ are cut in opposite sides of pavement or foot-wall and at right angles to it by hitch cutters made of $\frac{7}{8}$ inch steel, 1 foot to 2 feet long, driven by 6 lb. hammer having 28 inch handle. Posts or "trees," 10″ x 10″ are placed in holes at intervals of 3 feet, and are mounted by cap pieces 10″ x 10″ supporting the lagging, which is 2 to 4 inches thick, wedged between the cap pieces and hanging-wall. See drawing No. 4 for method of timbering slope.

A partition divides the shaft for the ladder-way and the tub-way, these being 3 and 9 feet wide, respectively. A dividing post 8″ x 8″ is placed under each cap piece, and 3 inch plank is spiked to dividing posts. Ladders having inclination of lode are in 18 foot lengths, with rungs 18 inches long and 14 inches apart, and a landing is provided at the foot of each ladder. The Cameron pump used for removing the water from the mine is hung in the ladder-way and rests on the foot-wall. The wires for discharging blasts find a safe conduit through the same compartment. The pavement of tub-way is provided with slides, 16″ apart, of 6″ x 6″ fir poles spiked on "bed pieces," or sills, which rest on pavement, and are attached to foot of the trees. At the surface the tub-way is provided with trap-doors that meet at an angle of about 90°. The ascending tub opens them, and they drop back into position by the force of gravity. See sketch No. 1.

Blasting.—See drawing No. 5 for arrangement of drill-holes. (a) and (b) are driven to a depth of 9 feet, at an angle of about 60° to horizontal towards (g); (c) and (d) to a depth of $8\frac{1}{2}$ feet; (e) and (f) to a depth of 8 feet in same direction. Shots in (a) and (b), (c) and (d), (e) and (f) are discharged in order as arranged. For method of wiring see drawing No. 6. The holes are drilled by $\frac{7}{8}$ inch octagon steel drills, with 5 lb. double face hammers. Twenty holes are required in an area of 14′ x 8′. The magnetic battery in use is manufactured by the Dominion Electric Co. The explosive here in use is called "rippite," and has the following composition, being somewhat similar to that of the well-known explosive gelignite :

Nitro-glycerine	$59\frac{1}{2}\%$ to $62\frac{1}{2}\%$
Nitro-cotton	$3\frac{1}{2}\%$ to $4\frac{1}{2}\%$
Nitrate of Potash.....	18 % to 20 %

Oxalate of Ammonia	9 % to 11 %
Castor oil	½% to 1½%
Wood meal	3½% to 5¼%
Moisture	1%

It is claimed that there are no injurious after effects due to smoke and gases, from the use of " rippite," neither is it affected by sudden changes in temperature.

Ventilation.—The mine is ventilated naturally. The air enters the main shaft and passes out through the air shaft. The direction of air current is determined by arrangement of doors at mouth of shaft, and by escape of exhaust steam from the Cameron sinking pump in the air shaft, which aids the natural ventilation. See map No. 3.

STAFF, SCALE OF WAGES, ETC.

The property is managed by Mr. Geo. J. Ross, a locally well known mechanical and mining engineer.

Foreman	$3.00 per day.
Hoistmen, who are also Blacksmiths	$2.00 "
Miners	$1.75 to $2.00 "
Bank men and surface men	$1.50 "

Two shifts are worked in 24 hours. Eight tubs of muck, each weighing 500 lbs., are raised per hour at a cost of 25c. per ton.

The men are provided with board and lodgings in the Company's cook-house, at a cost of $4.00 per week.

TRANSPORTATION.

The most convenient shipping points at present are from South River station, on the Intercolonial railway, and County Harbour, Guysborough county, distant 17 and 15 miles respectively. The mine occupies an elevated position with respect to shipping points, hence the slope of grades is favourable for transportation. The grades are gentle, because the roads meander around the hills and follow the tortuous courses of the streams. The soil is of a gravelly nature, the bridges are short; hence the conditions for " good roads in bad weather " are as nearly ideal as can be ob-

tained in the province. However, it is not expected that traction or animal transportation will be the method in use for any considerable time. A line of railway has been located from New Glasgow, Pictou Co., to County Harbour, Guysboro Co., with a branch line from Antigonish through the Copper Lake district, to connect with the New Glasgow and County Harbour road at the foot of Lochaber lake. When the prospective road becomes a reality, the transportation problem will be solved. (See map No. 2: dotted line represents proposed road.) In the meantime only high grade ore can be profitably shipped, but if the low grade ores prove suitable for concentration, as is probable, the Company will erect a concentrating plant, and will thus be able to market the whole output. The fact that the mine is only 70 miles from the Pictou smelter, with which it will soon have direct railway connection, and that the smelters of the Eastern States can be cheaply reached by water, increase to a considerable extent the value of the property.

ECONOMIC CONDITIONS.

The forests in the near vicinity of the mine have not suffered from the ravages of the portable saw mill, consequently there is an abundance of wood available at a relatively low cost for fuel, timbering and all mining operations. A number of skilled laborers, trained in the gold and coal mines of the province, are residents in the neighbourhood and near localities, and their services are being obtained by the Company at a moderate rate of wages. There is considerable water power available for all mining purposes in the near vicinity of the property. This can be developed and transmitted electrically to the mine. The country is a rich agricultural one, and when the considerable distance from market is taken into account, it is evident that superior farm produce can be obtained at low prices. In fine, all conditions which make for minimum expense in operation are here found.

ORGANIZATION.

The Lake Copper Mining Company, Ltd., is a company organized under the laws of Nova Scotia for the purpose of operating the Lake vein deposit at Copper Lake, Nova Scotia, and other

rich mineralized territory containing ores of copper. The capitalization of the company is $5,000,000, divided into 5,000,000 shares each having a par value of $1.00, fully paid and non-assessable. There have been placed in the treasury 2,500,000 shares. Funds received from the sale of treasury stock will be expended for the further development and equipment of the Company's properties. There is no preferred stock.

APPENDIX

APPENDIX.

PETROLEUMS AND COALS.

COMPARED IN THEIR NATURE, MODE OF OCCURRENCE AND ORIGIN.

By EUGENE COSTE, E.M., Toronto, Ont.

COMMUNICATIONS TO THE AUTHOR OR TO THE SECRETARY.

MR. G. H. PERKINS, State Geologist, Burlington, Vt.:—I am much impressed by the force and careful arrangement of Mr. Coste's argument. It seems to me that he has made out a good case. I shall give the matter further study, but see no reason now why I should not accept Mr. Coste's views.

MR. W. B. DENNIS, Blackbutte, Oregon:—In developing the Black Butte Quicksilver mine we have frequently encountered pockets of bitumen, usually closely associated with the more heavily mineralized portions of the vein, and noticeably present wherever metallic mercury occurs. The pockets vary from the size of a pin head to that of a man's head, and in one place we encountered one as large as a wash-tub. The veins vary from the thickness of a sheet of paper to an inch and a half wide. In one instance we encountered a small fissure about three inches wide. One half of the space between walls was filled with bitumen and the other half with very rich cinnabar, marcacite, iron and sulphur.

The Black Butte Cinnabar deposit has been pronounced by geologists a distinct product of solfataric action, and the very frequent occurrences and constant association of so much carbon would seem to bear out Mr. Coste's very reasonable and logical theory of the volcanic origin of the petroleum series of hydrocarbon compounds.

MR. M. J. MUNN, U.S. Geological Survey, Washington:—After a somewhat preliminary examination of this paper I am convinced that it is by far the best presentation of the inorganic side of the argument yet written. While I am not prepared at this time to accept the universal application of Mr. Coste's theory, especially in the Appalachian regions, I recognize that on a number of important points it has placed the burden of proof upon believers in the organic origin.

MR. C. W. WASHBURNE, United States Geological Survey, Washington:—It seems to me that a very good general case has been made out in this paper. It is, however, very hard to apply the theory in some special instances where artesian water bodies lie below oil pools in which there is no water. In the Florence oil field, Colorado, which I have just studied, I cannot conceive how oil could have passed through fissures in the underlying Dakota sandstone without taking up more or less of the water with which the Dakota has always been charged. The oil of this field occurs in fissures in the Pierre shale of Cretaceous age and it is entirely dry throughout the field.

In connection with the solfataric origin of oil, the intimate association of solfataras with oil districts in the Baku and surrounding region is possibly significant. I have collected several hundred instances of the association of oil with igneous rocks, but I find a number of new and interesting ones in Mr. Coste's papers.

Traces of oil have recently been obtained from fissures in basalt in the fresh water Payette formation in southeastern Oregon. A very large gas well has been struck in these beds. The occurrence is interesting because it is several hundred miles from this region to any unmetamorphosed marine sedimentary rocks. The formations below the Payette exposed on the sides of the Blue Mountains are metamorphic slates, marbles and quartzites of Triassic, Carboniferous and possibly older age, underlain by Archean granite, etc. Dr. Hayes, who is now in Mexico, has noted the intimate association of oil with igneous bodies as mentioned in Mr. Coste's paper.

PROF. WM. P. BLAKE, Territorial Geologist, Tucson, Arizona:—In response to your very courteous invitation to discuss the subject I am induced to send some crude ideas which I have held on the subject, mere conjectural hypothesis not sustained by investigation, but which may have some suggestive value.

It has long seemed to me that volcanoes and explosive earthquakes have a direct connection with petroleums. The immense volume of smoke emitted at times suggests the presence of volatile hydrocarbons, fluid or gaseous. It may be said that the fancied smoke is only steam, but is it so? What are the facts? If smoke, imperfectly burnt petroleum is indicated. Explosive mixtures of air and gas may account for many earthquakes. I am inclined to the view that volcanos are the results rather than the cause of petroleums. The petroleum seems one of the constituents of the planet included in the original make up coming to us with other fluids and gases. We find hydrocarbons in the comets; why not let us have our share?

It may be asked where do we get the oxygen for subterranean volcanic combustion. The question is not easily answered but there seems ample evidence of combustion.

We cannot exclude water and steam as active agents in vulcanism. But we must admit the powerful agency of explosive mixtures of gas and air.

These random thoughts may invite discussion.

Mr. Coste has assembled in his paper a vast array of facts and suggestions.

THE MINERAL RESOURCES OF THE SERPENTINE BELT, QUEBEC.

By JOHN A. DRESSER.

COMMUNICATIONS TO THE SECRETARY:

MR. C. H. RICHARDSON, State Geologist, Vermont:—I have read with a remarkable degree of interest the recent paper of Prof. John A. Dresser, of McGill University, entitled "Mineral Deposits of the Serpentine Belt of Southern Quebec."

The paper comes home to me with peculiar satifaction, first, because it was my privilege during the summer of 1907 to spend some little time with Prof. Dresser and his associates in the Black Lake, Thetford and Broughton districts of Quebec, where the economic products of the serpentine belt are best developed and where the asbestos and associated iron ores have been most successfully worked; and secondly, it was my good fortune to enjoy the esteemed companionship and expert knowledge of Prof. Dresser for a brief period of time in June, 1909, in the study of the serpentine belt and its associated terranes in their southern extension across the International boundary into Vermont.

Here the same complex series of metamorphic rocks with their acid and basic intrusives prevail. Yet denudation seems to have been carried to a lower level, for the various members exposed to view lie nearer the basal complex.

The serpentine belt is well defined and practically continuous southward a distance of more than 50 miles to the Lamoille valley. Beyond this point it manifests itself here and there in beds of talc and steatite, to the east of the Green Mountain axis.

On the north side of the International boundary the peridotites and pyroxenites, which cut sedimentary strata of middle Ordovician age, seem, south of the line, to have invaded only pre-Cambrian and Cambrian terranes. This might imply the existence of two periods of the introduction of the ultra basic peridotite. While I have seen in the Canadian field the diabase forming a marginal or outer face of the peridotite and pyroxenite, in Vermont it directly cuts these rocks, thereby proving a much later period of intrusion than that of the peridotites. This condition is best observed about two miles south of the International boundary, near the village of North Troy. This phenomenon was photographed and described in my recent report on the geology of Newport, Troy and Coventry, Vermont, published in the last biennial report of the State Geologist.

I agree most heartily with the author that these intrusives are bathylitic in character and have only been brought into view by continual denudation. The peculiar hornblende granite which cuts the more basic intrusives through numerous dikes, and sometimes intimately associated with the larger masses, I have failed to find in the southern field, while with the author I have noted them in Canadian territory.

The most interesting phase of Prof. Dresser's paper to me is his discussion of the origin of the veins of asbestos, or chrysotile, or fibrous serpentine, because of its direct bearing upon my study of the development of asbestos on Belvidere mountain in Eden and Lowell, Vt.

The citations of various theories, as proposed by such well known authors as Drs. Pratt, Merrill, Ells, Cirkel and Low, seem especially felicitous, and may explain in full the origin of this economic product in their respective fields. I again concur most heartily with the author from observations made both in the Canadian territory and that of the United States, that there could never have been as many open fissures in the serpentine as there are now veins filled with chrysotile, and that the process of replacement of the wall rock has gone on contemporaneously with the development of the asbestos. Nowhere have I seen this phenomenon so perfectly illustrated as at the property of the Lowell Lumber and Asbestos Company, operated by Mr. M. H. Gallager, of Lowell, Vermont. Here most excellent hand samples

can be obtained which show hard and compact peridotite, largely olivine, well defined serpentine, the fibrous chrysotile with a perfect line of magnetite near the center, or sometimes near the outer margin of the asbestos vein. This would establish the author's theory that the film of iron ore constituted the beginning of the vein, that the growth of the chrysotile crystals was exogenous and commensurate with the serpentinization of the wall rock. Thus it may be seen that by whatever process the rocks may have been fractured they have been invariably opened to the numerous agencies of metamorphism, and that the transition has been first to serpentine and second to asbestos.

To the south of the International boundary the chromite and magnetite deposits are not so well developed as in the Black Lake, Thetford Mine and Broughton districts of Canada. The walls of the ore bodies are not usually well defined, and a general dissemination of the ore throughout the rock mass obtains. The longer axes lie parallel to the line of fracture or cleavage in the country rock and may have been converted into lens-shaped masses by regional pressure.

I concur most heartily with the author that these economic products have originated by primary segregation from the peridotite magma; for following the laws for the development of different species from a single magma, the more basic would be the first to solidify.

The paper upon the whole reflects the careful and systematic study of the author in the field, and becomes a very important contribution to our knowledge of the origin and importance of the mineral deposits of the serpentine belt of southern Quebec. True it is that the field is sufficiently large and of adequate economic importance to demand detailed investigation of this complex series of igneous and metamorphic rocks, for they are intimately associated with the commercial development of two countries.

DR. J. MACKINTOSH BELL, Director New Zealand Geological Survey, Wellington, N.Z.:—The resemblance existing between the rock and mineral combinations occurring in Quebec, described by Mr. Dresser, with those of the so-called "serpentine belts" of New Zealand, is very remarkable. In the serpentine belt near the town of Nelson, South Island, New Zealand, we have

deposits of chromite and copper sulphides (chalcopyrite and native copper with pyrrhotite), both of which have been mined in a small way. The rocks are pyroxenites, peridotites, and dunites, all more or less serpentinized. In the "serpentine belt" of Mount Arthur, also not far from the town of Nelson, deposits of asbestos of high quality occur. These have been but little explored.

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